THE EVALUATION OF THE EFFECTIVENESS OF TRAFFIC CALMING DEVICES IN REDUCING SPEEDS ON "LOCAL" URBAN ROADS IN NEW ZEALAND

By

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ABSTRACT

Austroads (2004) promotes speed based design when installing LATM's and states that "there is very little systematic information available on device crossing speeds; there is even less reliable information on whether or not 'operating speeds' can be given for a given type of device".

This research investigates the effectiveness of traffic calming devices on local roads in New Zealand, and compares the installation criteria and the resultant effects with the findings sourced from a literature review and complements work undertaken by the LTSA (2004) who recommended that:

a. A set of guidelines on traffic calming devices should be developed.
b. RCA's should assess the effects of the traffic calming devices.
c. Its Standards and Guidelines Steering Group, should develop a set of case studies to evaluate the overall effect of various types of traffic calming devices.

The findings of the literature review was that:

- Traffic calming devices must only be installed after considering the resultant effects, e.g. traffic volumes, speed, noise, vehicle type, community attitudes, vibration and comfort.
- Several devices conclusively reduce speed, and can be used without undertaking further analysis, i.e. raised tables, road humps, road cushions, slow points and perimeter threshold treatments.
- Limited information exists within New Zealand that can be readily accessed and the author has been unable to conclusively demonstrate their effectiveness in reducing speeds, i.e. centre blisters, kerb extensions, parking; mid-block medians, reduced lane width and carriageway narrowing.
- Several websites exist overseas with useful information.

The findings of the case studies was that:

- Of the 21schemes, 10 resulted in a statistically significant reduction in speed, while 2 resulted in a statistically significant increase in speeds.
- The majority of devices that have been installed have not always being installed in accordance with the findings of the literature review.
- Many RCA's install traffic calming devices without monitoring the resultant effects.
- The turnover in staff and lack of record keeping means that the industry as a whole is not learning, a situation compounded by no central database existing and being maintained.
- The spacing of devices often exceeded recommended guidelines.

It is recommended that:

- Land Transport develops a design guide focusing on the devices that conclusively reduce speed and the resultant effects.
- Further research is undertaken into the community acceptability of devices.
- A design guide is produced for new developments, in order to avoid storing an LATM at a later date.
- A 'traffic calming' website and discussion group should be set up similar to the ITE website.

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Glossary of Terms – General

Arterial Road	A road that predominantly carries through traffic from one region to another.
Austroads	The association of Australian and New Zealand road transport and traffic authorities.
Capacity	The maximum number of vehicles that can pass a given point on a lane or road during one hour under the prevailing road and traffic conditions, without unreasonable delay or restriction.
Carriageway	The portion of the road devoted particularly to the use of vehicles inclusive of shoulders and auxiliary lanes.
Deflection	The amount of deviation away from the straight line of travel.
Design	Can mean design of a scheme, installation, treatment or device. The distinction is important, and should be made clear in each case. (Thus, the term 'LATM design' can be ambiguous in this present context; it refers to scheme design - including the selection and location of treatments.)
Device	An individual engineering *treatment* inserted into a street carriageway.
Evaluation	The process of determining whether the outcomes are desirable, affordable or acceptable, properly involves those with an interest in the result, or at least an overt consideration of their requirements (cf. assessment).
Gradient	The longitudinal slope of a road or path usually represented as the ratio of a one metre rise to the horizontal distance or expressed as a percentage.
HCV[1]	Heavy commercial vehicle.
HGV[1]	Heavy goods vehicle.
Horizontal device	Any treatment involving horizontal deflections, or carriageway deviations aimed at influencing driver behaviour through change of path.
Intersection	The junction at which two or more roads meet.
ITE[1]	Institute of Transportation Engineers.
Land Transport New Zealand[1]	Land Transport New Zealand is a Crown entity formed on 1 December 2004 to take responsibility for land transport funding, and the promotion of land transport safety and sustainability.
LATM	Local Area Traffic Management - the use of physical devices, streetscaping *treatments* and other *measures* (including regulations and other non-physical measures) to influence vehicle operation, in order to create safer and more liveable local streets. (Note: The use of the acronym LATM as a noun to mean 'device' *[qv]*, common in some parts of Australia, is best avoided).
Local traffic area	A traffic analysis area usually bounded by arterial roads or other roads serving a significant road transportation function, or other physical barriers such as creeks, railways, reserves or impassable terrain.
Operating speed	The *operating speed* of a device as defined, as the point speed typically found at a particular device and layout.
Perimeter	The outer extremity of a local area, across which vehicles travel to enter or exit a local area.

Glossary of Terms (Continued) – General

Plateau[1]	The section of the raised table excluding the ramps.
RCA[1]	Road Controlling Authority.
Regulatory sign	A sign indicating an obligation to comply with an instruction given under order, regulation, Act, ordinance or by-law.
Road	Link in the network, which exists to carry traffic reasonably efficiently, on which severe traffic restraint is inappropriate (includes 'arterials', 'main roads' and other traffic routes).
Sight distance	The distance, measured along the road over which visibility occurs between a driver and an object, or between two drivers at specific heights above the carriageway in their lane of travel.
S.D.	Standard deviation
Street	A local road used primarily for access to abutting properties.
Street speed	The highest mean, 85th or any other percentile speed actually observed along the street.
TERNZ[1]	Transport Engineering Research New Zealand Limited.
Through traffic	Traffic with neither an origin nor a destination within the local area.
Traffic calming	In general, the reduction of the motor vehicle's intrusion into and impacts upon urban life, by moderating the quantity, speed or other characteristics of vehicular traffic (i.e. an outcome); commonly and more specifically (when in relation to local streets), analogous to LATM.
Transit New Zealand[1]	Transit New Zealand (Transit) is the Crown Entity responsible for state highways - the strategic roads and motorways that are about 12% (10,894 km) of all New Zealand's roads.
Vpd	Vehicles per day.
85th Percentile	The speed at or below with 85% of vehicles travel. May be referred to as 85th %ile.

Devices

Blister island	A wide oval concrete island positioned at the centreline (median) of a street that narrows the lanes, diverts the angle of traffic flow, and can be used to provide pedestrians with a refuge.
Carriageway narrowing[1]	As distinct from pinch points, is the reduction in carriageway width over the total length of the street.
Central island	The circular or other specially shaped central island constructed or marked at an intersection (roundabout), and around which traffic circulates.
Combination device	Any treatment that comprises combinations of vertical and/or horizontal devices.
Combi-Hump[1]	A hump combining two profiles catering simultaneously for cars and buses.
Courtesy crossing[1]	Surface material on the carriageway such as textured asphaltic concrete preceding small changes in vertical alignment which can be used by pedestrians as a place to cross, but are not marked as pedestrian crossings.

Glossary of Terms (Continued) – Devices

Driveway link	An extended form of slow point stretching for two or more property frontages, that provides a greater visual and physical impact on the street than a standard slow point.
Footpath	A path or way for walking, not for cycles or vehicles. May be referred to as a **sidewalk** (USA).
Fourteen foot long humps[1]	A raised hump across the road built to a parabolic profile.
Give way signs	Signs that assign priority at intersections.
H-Hump[1]	Alternative name for a Combi-Hump.
Kerb extension	A horizontal extension of the kerb into the roadway resulting in a narrower section of roadway. May also be referred to as **kerb blister, kerb protrusion, curb extension, curb bulb, bulbouts, kneckdowns, curb radius reduction.**
Lane narrowings	Methods to narrow the width of the road to reduce speed, and pedestrian crossing distances.
Left-In/Left-Out Island	A partial road closure incorporating a raised triangular island at an intersection approach that obstructs right turns, and through movements, to and from the intersection, street or driveway. May also be referred to as **forced turn island, pork chops, right turn islands, right in/out islands, forced turn channelisation.**
Mid-block median	A flush or raised island placed along the centre-line of the road that narrows the carriageway and can provide pedestrians with a safe place to take refuge.
Mini-roundabouts	Mini-roundabouts operate in a similar manner to roundabouts but often without splitter island. May be referred to as **intersection islands or traffic circles,** and are typically controlled by stop (yield) or give way signs.
Modified "T" Intersection	A three-way intersection treatment using raised medians, signage and other delineation to modify the priority and to slow and physically direct traffic through an intersection. May also be referred to as **realigned intersection, modified intersection .**
On street parking	The reduction of roadway width available for vehicle movement, by allowing motor vehicles to park adjacent to the kerb.
Pedestrian crossing	A marked crossing that designates pedestrian priority.
Pedestrian platform	A raised section of roadway located at an intersection or midblock constructed such that it matches the level of the adjacent footpath such that the surface/texture of the platform is significantly different to the footpath. May also be referred to as **Courtesy Crossings**. Some platforms may be marked as pedestrian crossings and referred to as **raised crosswalks.**
Perimeter threshold	A coloured and/or textured pavement surface that contrasts with the adjacent road alerting drivers they are entering a local traffic area. May also be referred to as an **entry statement, gateway** or **threshold treatment**.

Glossary of Terms (Continued) – Devices

Pinch point[1]	Pinch points create a width restriction in a carriageway by the use of some combination of islands or kerb extensions. May also be referred to as a **squeeze point.**
Raised intersection platform	A raised flat section of roadway extending across the apron of an intersection, ramped up from the normal level of the street.
Raised table	A flat top raised section of roadway ramped up from the normal level of the street and located midblock. May also be referred to as a **flat-top road hump, raised platform or speed table.**
"Rumble-wave" [1]	Comprises hot rolled asphalt laid in a sinusoidal profile.
Road bump[1]	Speed bumps are very short (usual width of 600mm–1,200 mm) with a height of 30 to 100mm and a circular or parabolic profile". May be also referred to as a **judder bar.**
Road closure – diagonal	A barrier placed across an intersection that forces traffic to turn, and prevents traffic from proceeding straight through the intersection. May be also referred to as **diverter, full diverter, diagonal diverter.**
Road closure – full	A method to restrict all traffic from continuing along the roadway, thereby resulting in one entry/exit and eliminating though traffic. May be referred to as **street closure, cul-de-sac, dead end.**
Road closure – half	A barrier to traffic at the intersection of two streets in which one direction of the street is blocked to traffic, but traffic from the other direction is allowed to pass through. May also be referred to as **half street closure, partial closure, one way closure, directional closure, semi diverter.**
Raised crosswalk[1]	A marked pedestrian crosswalk (pedestrian crossing) at an intersection or mid-block location constructed at a higher elevation than the adjacent roadway.
Road cushion	Form of road hump that allows non-car traffic (cyclists/buses/emergency vehicles) to pass unimpeded. May also be referred to as **speed cushion.**
Road depression[1]	Inverted road humps with drainage in the bottom.
Road hump	A curved raised area of a road used to reduce vehicle speeds and discourage through traffic use. Also commonly referred to as a **speed hump**.
Road thump[1]	A circular profile thermoplastic hump.
Roundabout	A channelised intersection at which all traffic moves around a central traffic island, which simplifies the allocation of priority.
S-Hump[1]	Similar to an H-Hump but the plan profile consists of continuous curves.
Shared zone	A length of carriageway in which vehicles are required by regulation to give way to pedestrians. May also be referred to as **shared space or woonerf.**

Glossary of Terms (Continued) – Devices

Sinusoidal hump	A road hump that incorporates curved transitions to minimise the impact of grade change.
Slow point	A series of kerb extensions on alternating sides of a road that narrow, and deflect the trafficable roadway - can be angled and can include a central median island or line-marking. May be referred to as **chicanes, chokers, deviations, serpentines, reversing curves, twists, lateral shifts, staggerings, jogs, axial shifts.**
Speed limit signs	Signs displaying reduced speed limits - may be implemented on an area-wide basis.
Tactile surface treatments	Low bumps, buttons, bars, grooves or strips closely spaced across or immediately adjacent to a street or path that draws attention to a feature or hazard, and can have a vibratory and/or audible effect when travelled over. May be referred to as **uneven road surface, cross pavement markings.**
Twelve foot long humps[1]	A raised hump across the road built to a parabolic profile.
Watts profile hump	A circular segment road hump designed to slow vehicles traversing them.
Wombat crossing	A flat-topped raised area of road similar to a raised table but with the top surface marked as a designated pedestrian crossing to give priority to pedestrians.

Notes:

- Unless noted[1], all terms as per Austroads (2004).
- As the terms used to describe devices vary considerably across the world, the terminology adopted by Austroads (2004) has generally been adopted but not exclusively so.

1. INTRODUCTION

Austroads releases numerous publications and guidelines for use by RCAs in both countries, including the Guide to Traffic Engineering Practice, Part 10: Local Area Traffic Management. A key principle in a Local Area Traffic Management (LATM) scheme is to control speed by installing traffic calming devices, which can be achieved by shifting vehicle paths horizontally, vertically, by narrowing the travelled path, or altering the road surfaces appearance or texture. While various publications are available, limited information exists on traffic calming devices used in New Zealand, and their effectiveness in reducing speeds.

The objective of this research as outlined in the research proposal (Appendix A), is to produce a design guide of traffic calming devices that are effective in reducing the speeds of traffic on mid-block urban 'local' roads. The primary outputs will include:

- A list of devices that have been used on local roads in New Zealand, and their effectiveness in reducing speeds midblock.
- Key features of those devices.
- Factors that need to be considered when deciding which devices may be appropriate for installation.
- Locations where the devices were installed including a description of the adjacent road environment including traffic volumes.
- Advantages and disadvantages of each device.

This will be achieved by:

- Listing devices used internationally in LATM schemes, in particular those where the extent of the speed reduction can be quantified.
- Comparing the effectiveness of those devices with those used in New Zealand.
- Providing information that will increase practitioners understanding of how the devices work, such that they can implement LATM schemes that are cost effective, and the effects have been considered during the design phase.
- Identifying areas that may benefit from further research.

2. METHODOLOGY

The research proposal outlines the proposed work for each of the key steps, i.e. data collection, literature review, data analysis and project outputs. This section highlights where the actual process differed from the proposed process, the difficulties experienced and the effects of these on the accuracy of the results for each step.

2.1 Data Collection

As the research relied heavily on the results of case studies, it was imperative that RCA's were contacted early during the study period (March 2005 to March 2006), in order to gain their support to assist with the project. As a result, some of data collection commenced prior to the literature review being undertaken.

The proposed process involved inviting all RCA's via letter early in 2005 to assist with the project, with the objective of setting up appropriate data gathering regimes prior to construction commencing using the standard survey form (Appendix B).

The actual process involved contacting 74 RCAs, 12 regional councils, 7 regional offices of Transit, 6 regional offices of the Land Transport Safety Authority (now part of Land Transport NZ), TERNZ, Opus Central Laboratories and suppliers of "traffic calming" devices.

The difficulties experienced included navigating around the websites, which are set up differently, and identifying who the key contact was, given that key personnel are not always listed. Contacts were generally identified via the Long Term Council Community Plan. Of the 135 invitations sent out, 15 RCA's were in a position to provide data. Of the 15, 8 were RCAs who participated in the 2004 survey of 33 RCAs, by the Land Transport Safety Authority. The primary reasons for being unable to assist included:

- Lack of resources.
- Other priorities.
- Not having installed any devices that would assist with the research.
- Lack of record keeping with respect to device installation dates, construction plans, no 'before' or 'after' traffic surveys undertaken or planned, and no recollection of the exact location where traffic surveys were undertaken.
- Lack of funds to enable 'after' traffic surveys to be undertaken.

It is possible that the complexity of the survey form may have discouraged RCA's from completing it. None of the RCA's that provided information used the survey form, with the majority of the information collected via e-mail, phone calls, construction drawings and aerial photographs.

Some RCA's were willing to assist but were not in a position to be able to provide the data required in time for inclusion in this report, or could not provide data on completed schemes, such that any meaningful conclusions could be formulated. The RCA's and associated schemes, which could form the basis of future research, include:

- Buller District Council, proposed scheme involving the installation of road bumps in The Strand in 2006.
- Christchurch City Council, existing scheme involving a single lane angled slow point in Fifield Terrace.
- Gisborne District Council, existing schemes comprising road humps and angled slow points.

- Manukau City Council, proposed scheme involving the installation of midblock medians (three abreast) in McKean Avenue, currently on hold subject to funding becoming available.
- Papakura District Council, proposed schemes involving the installation of road humps at eight sites.
- Palmerston North City Council, proposed schemes for North Street and Rangiora Road.
- South Taranaki District Council, existing scheme on Camberwell Road comprising a raised table and a slow point.
- Tauranga District Council, existing scheme involving the installation of 75mm high circular road humps in Lee Street.

2.2 Literature Review

The proposed process involved accessing the University of Canterbury's Transportation Engineering portal (http://library.canterbury.ac.nz/eng/entr/) and collecting information on devices, using keywords such as 'traffic calming' and 'speed management' from a variety of sources including:

- Databases, i.e. Science Direct, Proquest, Compendex, Web of Science, TRIS.
- Electronic Journals.
- Websites (Appendix C).
- Libraries, i.e. Te Puna (Library of New Zealand); University of Canterbury Library; DCC library.

The difficulties experienced included:

- Different terminology being used for the same device between countries, and within the same country, e.g. kerb extension (Austroads) vs bulbout (USA).
- Being restricted to English language websites.
- Few websites having a dedicated electronic technical library relating to traffic calming where users could view selected reports, participate in discussions and view other links, with the exception of:
  - ⇒ SWOV, Institute for Road Safety Research (Netherlands) -http://www.swov.nl/en/zoek/index.htm.
  - ⇒ Institute of Transportation Engineers (United States of America) - http://www.ite.org/.
  - ⇒ Department for Transport (United Kingdom) - http://www.dft.gov.uk/ .
- Identifying the document but not always being able to obtain it, due to either organisations not responding to requests or the University of Canterbury imposing restrictions on what publications could be sourced from overseas.
- The volume of information available in certain areas made it difficult to decide what to include in the report, such that the focus remained on the project objective.
- Altering the proposed classification system to tie in with Austroads (2004) that was purchased after the literature review had commenced.

In addition:

- Several RCA's did provide copies of policies (without prompting) for investigating and prioritising LATM schemes, but none provided (or were asked) if they had formal documentation on the installation criteria and resultant effects. This possibly reflects (LTSA, 2004) where it was reported that "there was strong support for the development of guidelines or a set of best practice examples, with 31 of the 33 RCA's supporting the proposal".

- Only one New Zealand publication was identified (Dravitzki & Munster 1997).

2.3 Data Analysis

Data analysis can be effected by the quality of the data collected, as highlighted by Ewing (1999a), who pointed out several caveats that exist with respect to the accuracy of data collected in 'before' and 'after' studies:

- "Rarely in 'before' and 'after' studies is it made clear where speed measurements were taken. Occasionally a study will report 'midpoint' or 'midblock' speeds, but since the spacing of slow points or the length of blocks is unknown, the exact location of measurements is also unknown".
- "...the exact date of the measurement is not known. The 'before' measurement may be one month or three years before installation, the 'after' measurement one week or two years afterward. The exact time of measurement may affect results due to the natural growth of traffic and the tendency of travellers to adjust to the new measures".
- "While sample sizes for some measures are large, and sample averages are thus likely to be close to true averages by virtue of the *law of large numbers*, sample sizes for other measures are minuscule".

The proposed process involved:

- Comparing the results of the 'after' surveys to the 'before' surveys, and the expected results as identified in the literature review.
- Comparing the results of the 'after' surveys to the expected results identified in the literature review.

The actual process was as proposed, however the caveats referred to by Ewing were found to be applicable to some of the data collected from the literature review and the case studies, thereby resulting in firm conclusions being unable to be made, i.e.:

- Some RCA's only undertook 'after' surveys and some only 'before' surveys.
- The description of where the surveys were undertaken was not always clear, and different descriptions were sometimes used for 'before' and 'after' surveys undertaken at the same location.
- Speed surveys undertaken at devices were generally completed using hand held radar, which introduces some variability with respect to the exact location of the vehicle when the speed measurement is recorded.
- Where 'before' and 'after' surveys were undertaken in exactly the same location, they were not always undertaken midway between the device, as the locations of the devices were governed by other factors than the survey location.
- The number of schemes supplied by RCA's involving similar devices were so few that comparison between similar devices used in different schemes was not possible.

2.4 Project Outputs

Following completion of the literature review and after receiving the initial data from participating RCA's it was apparent that

- Other effects such as traffic volumes, crash risk and pedestrian safety must be taken into account when selecting devices where the primary objective is to reduce speed. It was beyond the scope of this report to investigate each of these effects in detail, but where they were identified as part of the literature review, reference has been made to the extent of the effect.

- All traffic calming devices installed along a local urban road including those at intersections should be considered for investigation, as many LATM schemes use a mixture of devices.

The scope of the study was altered to:

- Define the concepts of speed management, traffic calming and LATM schemes.
- Define device classification systems.
- Discuss the general theory as to how devices work.
- Rank the effectiveness of the device in reducing speeds and the resultant effects based on the available evidence as per Table 2.1.

Table 2.1: Available evidence to support the assertion that devices affect a change in speed (+ ve or – ve)

Available evidence	**Background Information**	**Installation Guidelines**
Strong (S)	• Several studies with similar conclusions, or • Scholarly journals/reports/recognised publication with detailed analysis.	Install device, speed reductions likely to be similar to literature review.
Moderate (M)	• Scholarly journals/reports/recognised publication with limited analysis.	Install device, monitoring 'before' and 'after' effects recommended.
Limited (L)	• Several studies with conflicting conclusions; or • Scholarly journals/reports/recognised publication with results of a trial; or • Scholarly journals/reports/recognised publication recommending that further investigations are required to confirm the initial findings. • The relevant information was not able to be identified during the literature review	Install device as a 'trial' with monitoring 'before' and 'after' effects mandatory.

- Present the data collected in New Zealand as a series of case studies, and comment on the differences between the case studies and the key findings of the literature review.
- Identify future opportunities for further research including:
  - ⇒ How data may be gathered, stored and distributed in New Zealand to facilitate access by all practitioners.
  - ⇒ For those devices identified during the literature review that conclusively reduce speed, list some unresolved issues that could be investigated to improve our understanding of how the devices work.
  - ⇒ Highlighting how New Zealand practice could be improved with respect to installing traffic calming devices on 'local roads'.

3. LITERATURE REVIEW

Significant research (TAC 1998; Ewing 1999b; Austroads 2004; CSS/IHT 2005) has been undertaken with respect to traffic calming devices. Of the above publications, Austroads (2004) states that "there is very little systematic information available on device crossing speeds; there is even less reliable information on whether or not 'operating speeds' can be given for a given type of device".

LTSA (2004) recommended that following a series of interviews with staff of 33 of the 74 RCA's in New Zealand, that:

(a) Its Standards and Guidelines Steering Group, should facilitate the development of guidelines on traffic calming devices.

(b) RCA's should assess the effects of the traffic calming devices.

(c) Its Standards and Guidelines Steering Group, should develop a set of case studies to evaluate the overall effect of various types of traffic calming devices.

This research will:

- Assist practitioners to understand how traffic calming devices work.
- Assist Land Transport New Zealand into partially fulfilling recommendations (b) and (c) above.
- Provide Land Transport New Zealand with some guidance on how to implement recommendation (a).

3.1 Speed Management/Traffic Calming/LATM

Prior to reviewing the available devices, practitioners need to understand the concepts of speed management, traffic calming and LATM schemes individually as well as in the wider context.

Speed management is "...about *regulating* the speed (passability) of cars through legislation, markings, visual or physical effects" Kjemtrup & Herrstedt (1992)

Traffic calming is "... the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behaviour and improve conditions for non-motorised street users" (Lockwood 1997). Furthermore, it may include a variety of measures; physical, social, environmental, cultural that can be applied locally, regionally or city-wide. The following definitions (Brindle 1991) explain the different levels of traffic calming:

- Level 1 traffic calming involves "actions to restrain traffic speed and lessen traffic impacts at the local level, where traffic volumes, levels of service and capacity are <u>not</u> an issue".
- Level 2 traffic calming involves "actions to restrain traffic speed and lessen traffic impacts at the corridor (intermediate) level, where traffic volumes, levels of service and network capacity are an issue".
- Level 3 traffic calming involves "actions at the macro-level, to lessen traffic levels and impacts city-wide".

LATM is "the use of physical devices, streetscaping *treatments* and *other measures* (including regulations and other non-physical measures) to influence vehicle operation, in order to create safer and more liveable local streets"

Austroads (2004). LATM is concerned with the planning and management of the usage of road space within a local traffic area, often to modify streets and street networks which were originally designed in ways that are now no longer considered appropriate for the needs of residents and users of the local area.

Table 3.1 illustrates the relationship between speed management, traffic calming and LATM via the Darwin matrix , which resulted from an informal discussion by a group of Western Australian practitioners at the 15th ARRB conference in Darwin.

Table 3.1: The Darwin matrix

Scope of Measure	Type of Measure	
	E - Physical/Environmental, ('Technique')	**C** - Social /Cultural, ('Ethos')
L Local (street or neighbourhood)	**LE** LATM/Residential Street Management; **Speed Control Devices**; "Green Streets" programme. Most reported speed and accident physical countermeasures.	**LC** Neighbourhood Speed Watch; Vicroads "Speed and Volume" study; Community action; Attitudinal change
I Intermediate (Zone, precinct, corridor, regional)	**IE** Environmentally adapted through roads (Denmark); Shared Zones, Lower speed zones; Pedestrian shopping precincts: Corridors; Road pricing (precinct): Parking policies	**IC** Voluntary behaviour changes: mode choice: speed
M Macro (city wide)	**ME** Travel Demand Management (TDM): Transportation Systems Management (TSM): Total systems measures (fares policy, city wide road pricing) Manipulation of urban form and infrastructure: Parking policies	**MC** Cultural change: Loss of Choice (eg energy constraints, significant drop in living standards): Population decline: Futurology

(Source: Brindle 1991)

Clearly, "The evaluation of the effectiveness of traffic calming devices in New Zealand in reducing speeds on 'local' urban roads falls into category 'LE'.

3.2 Traffic Calming Device - Classification Systems

Table 3.2 illustrates some device classification systems.

Table 3.2: Traffic calming devices – Classification systems

Source	Category	Description
Vis, Dijkstra & Slop (1992) cited in van Schagen (2003)	Informative	The road users are alerted to the fact that a particular kind of behaviour is expected from them, e.g. the maximum speed sign.
	Suggestive	The road users are subconsciously urged to adopt a certain kind of behaviour, e.g. special paving construction.
	Persuasive	The road user is (more) clearly persuaded to behave in certain manner, e.g. road humps.
	Obstructive	Specific (traffic) behaviour is physically forced on the driver.
(TAC 1998; Austroads 2004)	Vertical	Deflection devices are vertical changes in the course or path of a vehicle introduced as a result of a physical feature of roadway.
	Horizontal	Deflection devices are designed to change the horizontal course or path of a vehicle as a result of a physical feature of roadway.
(TAC 1998; Austroads 2004)	Signage, Line Marking and other treatments	Signage and line marking can be used to regulate and/or calm traffic.
(TAC 1998; Austroads 2004)	Obstructive/Diversion	Devices are used to redirect traffic.
(Austroads 2004)	Integrated treatments	Are a combination of devices.

As Austroads guidelines are used by many RCAs in New Zealand, the Austroads categories have been adopted in this report. Integrated treatments are not discussed as they comprise of devices that are covered by the other categories.

3.3 Traffic Calming Devices - Vertical

3.3.1 Background

In addition to the effects that a device will have on speed, volumes and crashes, other effects to consider when installing vertical traffic calming devices may include comfort, ground clearance and tracking width.

Comfort

Devices affect comfort levels by inducing vertical acceleration differently, such that vehicle occupants are generally unwilling to accept peak vertical acceleration in excess of 0.7g (where “g” is the acceleration due to gravity and equals $9.8m/s^2$). For example:

- Road bumps induce high vertical accelerations at low speeds because they are significantly shorter than the wheelbase of a vehicle. "the acceleration decreases with higher speeds due to absorption of the impact by the vehicle suspension" (Braaksma & Weber 2000).
- Road humps "work by transferring an upward force to a vehicle, and its occupants as it traverses the hump. The force induces a front to back pitching acceleration in vehicles having a wheelbase similar in length to the hump that increases as the vehicle travels faster" (Braaksma & Weber 2000).

Ground Clearance

Vehicle ground clearance is governed in New Zealand by Land Transport (2002), which specifies that for:

- Heavy rigid vehicles the minimum ground clearance is 100 mm.
- Light rigid vehicles there is no minimum ground clearance requirement, however, if a light motor vehicle's suspension is modified so the ground clearance is under 100 mm, a Low Volume Vehicle Certifier must approve the modified suspension.

Vehicle Tracking Width

Some devices such as road cushions are not favoured in parts of the world (e.g. USA) as the tracking width between private motor vehicles and trucks are similar, as illustrated in Appendix D.

Vertical devices that allegedly reduce speed include road bumps, road humps, raised tables, road cushions, road depressions and raised intersection platforms. Each device is discussed in turn, supplementing Austroads (2004), covering background and effects.

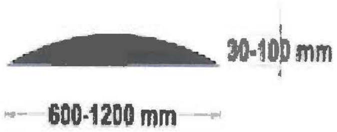
3.3.2 Road Bumps

Types of road bumps include:

- "Thermoplastic road thumps". They were developed by the Wakefield Metropolitan District Council (UK) in 1990, as an alternative to standard road humps.
- "Asphaltic road humps". "Italy introduced the extensive use of speed bumps in 1990 in an attempt to limit the high number of fatalities involving pedestrians in urban streets, caused by the high speed of vehicles" (Pau & Angius 2001).
- Concrete judder bars.

Road bumps are described as "very short (usual width of 600-1,200mm) with a height of 30–100mm and a circular or parabolic profile" (Pau 2002), and are illustrated in Figures 3.1 and 3.2.

Figure 3.1: Road bump, Cross section



(Source: Pau 2002)

Figure 3.2: Thermoplastic "Thump"

(Source: DOT 1994b)

Road bumps are not referred to in Austroads (2004) and the issues to consider (DOT 1994b) are:

- They should extend right across the carriageway.
- They should be installed on roads with a speed limit less than 50 km/h and in conjunction with other measures.
- They should generally be installed at 50m intervals.
- They are cheap, relative to other devices.
- They may experience some flattening at the edges, particularly with the first thump, a condition compounded by hot weather.

The effects are:

- Traffic volumes - DOT (1994b) reported in a trial involving a 750m long road with a 48 km/h speed limit, that volumes had reduced by 23% after one year.
- Pedestrian safety, noise and comfort - No information could be sourced.
- Crash risk - Pau (2002) found in a study performed on 10 road bumps (600mm wide with a circular profile and 30mm high) installed on several streets with a posted speed limit of 50 km/h, involving observations of 23,000 vehicles and 1,900 motorcycles, that drivers suddenly slowed before the bump, increasing the probability of minor accidents involving 'nose to tail'. Furthermore, that road bumps are very dangerous for the stability of motorcycles (especially under wet conditions) because the narrow profile of the undulation can make equilibrium precarious and that "...in 8 sites out of 10, more than 50% of users carried out avoidance manoeuvres".
- Speed – DOT (1994b) reported on a scheme where thumps were installed at intervals varying between 35m and 75m on a road carrying approximately 2,700 vpd, with a 30 mph (48 km/h) speed limit that the:
  - Mean speed along the road, reduced from 30 mph (48 km/h) to 23 mph (37 km/h).
  - 85th percentile speed along the road reduced from 34 mph (55 km/h) to 29 mph (47 km/h).
  - Mean and 85th percentile speeds at the thumps were 22 mph (35 km/h) and 28 mph (45 km/h) respectively.

  Pau (2002) found that:
  - The effectiveness of these devices in reducing speed was very poor.
  - A maximum reduction in the 85th percentile speed at the bump of 5.4 km/h.
  - Drivers tended to increase speed once past the bump, with speeds at 4 of the sites greater than the posted speed limit within 20m of the undulation.

No information was available on the spacing of the bumps, and when the 'before'/'after' surveys were undertaken relative to the construction. The results are consistent with previous studies (Watts 1973; Mak 1986; Stephens 1986; Zaidel et al. 1992; ITE 1997) cited in Pau (2002), showing that larger devices are more useful than narrow bumps in reducing traffic speed.

"In some countries (United Kingdom, the Netherlands, Denmark, Germany, the United States, Australia and Israel), road bumps have been replaced with better designed and more functional humps or cushions" (Pau 2002).

The key points are:

- Strong evidence exists that road bumps are ineffective in reducing speeds.
- Road bumps are being replaced with better designed and more functional humps.
- Road bumps increase the risk of crashes occuring, particularly for motor cyclists.

3.3.3 Road Humps -Overview

Road humps vary in height between 70 and 120mm and come in a variety of profiles including sinusoidal, circular, and parabolic. In addition to the information provided in Austroads (2004), issues to consider when installing road humps are as follows:

- Attitudes - Webster & Layfield (1996) found in a study that attitudinal surveys indicate that the majority appear to support road hump and raised table schemes.
- Location:
  - Road humps should only be installed on streets with a speed limit ≤ 30 mph (Hass-Klau et al. 1992), and ≤ 50 km/h (TAC 1998).
  - "the applicability in terms of peak hourly volume for all three types is up to a maximum of 600 motor vehicles" (Hass-Klau et al. 1992).
  - "they are not permitted on trunk roads" (Hass-Klau et al. 1992).
  - Locations to avoid include streets used by articulated buses, due to potential decoupling (TAC 1998).
- Gradients – 75/100mm high humps have been installed on roads serving as bus routes with grades of between 5 and 10%, without any apparent problems.
- Dimensions - Typical dimensions for local street humps are 4m long and 80mm high, with a sinusoidal cross section (TAC 1998).
- Grounding - DOT (1996) reported that sports cars can have unladen ground clearances as little as 100mm, reducing by approximately 30mm when fully laden, and studies have shown that longitudinal straddling can occur when the vehicle has a longer wheel base than the hump, and that to limit the possibility of grounding, road humps generally should not exceed 75mm in height.

In addition to the information provided in Austroads (2004) the effects are:

- Traffic volumes - Webster & Layfield (1996) found in a study of 18 schemes involving in excess of 300 x 75mm circular road humps, that volumes had reduced by between 2 and 43%, and on average 24%. The studies confirm Austroads (2004) advice.

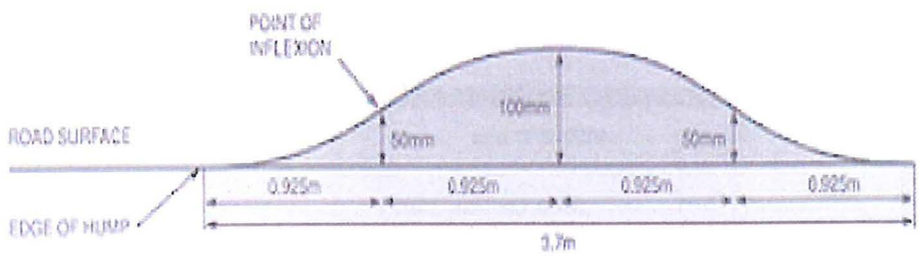
- Pedestrian safety - Will increase (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk - Finch et al. (1994) cited in Webster & Layfield (1996) found that a 1.6km/h reduction in speed resulted in a 5% reduction in crashes. Other studies (Webster 1993; Mackie & Webster 1995 cited in Webster & Layfield 1996) have confirmed that a 14 to 16 km/h reduction in mean speeds, will result in a 65% reduction in injury accidents. The studies confirm Austroads (2004) advice.
- Noise - (Abbott et al. 1995 cited in Webster & Layfield 1996) found reductions in daytime noise of between 2dB(A) and 4dB(A) at and between 75mm high road humps and cushions, noting that a 3dB(A) change is the minimum difference generally detectable by the human ear.
- Comfort - Because of passenger discomfort, 100mm high humps are usually not suitable for bus routes or where emergency services may be expected to pass the humps on a regular basis. Kennedy et al. (2004) found in a study of 75mm high sinusoidal, round top and flat humps, that the peak vertical acceleration was:
  - Below 0.7g for car drivers travelling at 32 km/h and minibus/ ambulances travelling at 24 km/h.
  - Slightly above 0.7g for the bus drivers travelling at 24 km/h travelling over the flat top and sinusoidal humps.

  Subsequently it was recommended that a top length of 3.7m (circular profile) be used, as a good compromise between effectiveness and possible grounding.

3.3.3.1 Sinusoidal Humps

Sinusoidal humps were developed in "the Netherlands and Denmark to provide a comfortable ride for cyclists in traffic calmed areas" (Kennedy et al. 2004).

Figure 3.3: Sinusoidal hump – Cross section



(Source: DOT 1998b)

In addition to the information provided in Austroads (2004), Hass-Klau et al. (1992) cited design information relating to sinusoidal shaped humps from the Netherlands, as illustrated by Table 3.3.

Table 3.3: Road hump dimensions - Dutch examples

Speed Limit	20 km/h	30 km/h
Height (m)	0.12	0.12
Hump spacing (m)	30, where the desired maximum speed between humps is 25km/h	50, where the desired maximum speed between humps is 35km/h
Total length (m)	3.36	4.80

(Source: C.R.O.W 1998, cited in Hass-Klau et al. 1992)

In addition to the information provided in Austroads (2004), DOT (1998d) reported that the mean speeds on streets where 100mm high sinusoidal humps had been installed, had reduced from 33 mph (53 km/h) to 15.5 mph (25 km/h) at the humps spaced 100m apart.

The key points are:

- They are generally installed to provide a more comfortable ride for cyclists.
- Limited evidence was sourced to illustrate the effectiveness of sinusoidal humps in reducing speed, and the resultant effects.

3.3.3.2 100mm and 75mm high Round/Dome/Circular Shaped Humps

A raised hump 3.7m long, constructed across the road to a circular profile with a maximum height of 100mm, is commonly referred to as the Watts profile hump. Problems with the Watts high profile hump with respect to grounding and comfort led to the development of 75mm high humps, thereby allowing a good compromise between speed reduction for cars, without causing too much difficulty for buses and emergency services.

Figure 3.4: Circular hump – Cross Section

(Source: Pau 2002)

In addition to the information provided in Austroads (2004) the effects are:

- Comfort - Braaksma & Weber (2000) reported on the results of an experiment where cars and transit buses were driven over two circular humps of different heights, 100mm and 75mm respectively as illustrated in Table 3.4.

Table 3.4: Circular humps – Peak vertical accelerations

Observed 85th percentile speed (km/h)	Test Vehicle	Peak Vertical Acceleration (g)	RSS[3] acceleration (g)
25[1] (29)[2]	1989 Suzuki Swift GTi	0.67 (0.56)	0.17 (0.15)
25[1] (29)[2]	1997 Chevrolet Monte Carlo LS	0.57 (0.33)	0.18 (0.12)

(Source: Braaksma & Weber, 2000), [1] – 100mm high hump, [2] – 75mm high hump, [3] – Root Sum Square

(Kennedy et al. 2004) found in a subsequent study that the peak vertical acceleration was below 0.7g for cars travelling across a 75mm high hump at 32.2 km/h.

In Table 3.4 the peak vertical acceleration for the 100mm high hump is approaching 0.7g, and is substantially more than for the 75mm high hump.

- Speed - Hawley et al. (1993) reported that following a series of trials of Watts profile humps "...that the mean speeds at humps are 22 km/h" and were identical to those obtained by TRRL. Webster & Layfield (1996) found in a study involving 12 schemes, and in excess of 140 humps, that the mean and 85th percentile speed across 75mm high circular humps was 23.7 km/h and 30.6 km/h respectively.

The key points are:

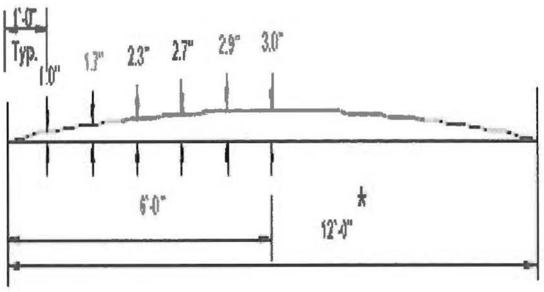
- Strong evidence was sourced to illustrate the effectiveness of circular humps in reducing speed, and the resultant effects.
- The abruptness of Watts profile humps has led to the development, and adoption of lower height circular humps and alternative hump profiles.

3.3.3.3 12 foot long hump (USA)

12 foot long humps are not referred to in Austroads (2004), and the issues to consider when installing the humps (Ewing 1999b) are:

- The 12 foot long (3.66m) hump is a raised hump across the road built to a parabolic profile, with a maximum height of either 3" (75mm), 3.5" (90mm) or 4" (100mm) as illustrated in Figures 3.5 and 3.6.
- The 12 foot long hump is the most common traffic calming device in use in America, and is the only device for which design and installation standards have been prepared by the ITE.

Figure 3.5: 12 foot long hump, 75mm high – Cross section



(Source: VDOT 2002)

Figure 3.6: 12 foot long hump - West Palm Beach

(Source: Ewing 1999b)

The effects are:

- Traffic volumes - Ewing (1999a) reported on a study, involving 143 sites where 12 foot long humps had been installed, that traffic volumes reduced by 18%.
- Comfort - "The rough ride caused by the 4 inch high, 12 foot high long humps is another issue. Most communities now limit the height to 3 to 3.5 inches…" (Ewing 1999b).
- Speed - Ewing (1999b) reported that the 85th percentile speed across the hump is between 24 and 32 km/h, and based on studies of 179 sites (Ewing 1999a), the downstream effects of traffic calming measures for 12 foot humps are:
  - Mean 'after' traffic calming = 44 km/h, S.D. = 6.4 km/h.
  - Average reduction in mean speed = 12.2 km/h, S.D. = 5.6 km/h.

While an effective device, it appears other effects preclude it being used in favour of other devices. Ewing (1999b) reports that speed tables are being promoted as an alternative device, and some districts such as Fort Lauderdale, are restricting 12 foot long humps to roads carrying between 500 and 3000 vpd.

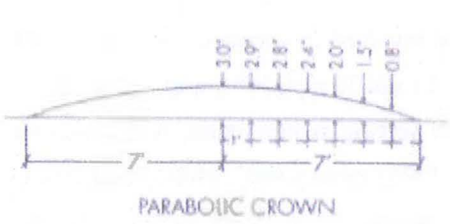
The key points are:

- Strong evidence was sourced to illustrate the effectiveness of the 12 foot long humps in reducing speed, and the resultant effects.
- The abruptness of the 100mm high humps has led to most communities adopting a maximum height of between 75 and 90mm, and has led to the development of longer profile humps.

3.3.3.4 14 foot long hump (USA)

One of the longer profiles developed is the Portland 14 foot long (4.27m) hump, i.e. a raised hump across the road, built to a parabolic profile with a maximum height of 75mm.

Figure 3.7: 14 foot long hump, 75mm high – Cross section



(Source: Atkins & Coleman 1997)

Figure 3.8: 14 foot long hump - Portland

(Source: Ewing 1999b)

14 foot long humps are not referred to in Austroads (2004), and the issues to consider when installing the humps (Ewing 1999b) are:

- They should generally be installed on 'local' roads, as per 12 foot long humps.
- They give a gentler ride than the 12 foot hump, because of its greater length in the direction of travel.
- They are difficult to construct, such that the exact profile is replicated.

The effects are:

- Traffic flow - Ewing (1999a) reported on a study involving 15 sites where 14 foot long humps had been installed, that traffic volumes had reduced by 22%.
- Delays - Atkins & Coleman (1997) found in a study that they can cause unnecessary delays to emergency vehicles on designated emergency routes, i.e. the installation of 14 foot long road humps resulted in delays varying between 1 and 9.4 seconds per device for emergency vehicles.
- Speed - Ewing (1999b) reported that the 85th percentile speed across the hump is approximately 5 km/h higher than the 12 foot long hump, and based on studies of 15 sites (Ewing 1999a), the downstream effects of traffic calming measures for 14 foot long humps are:
  - Mean "after" traffic calming = 41.1 km/h, S.D.= 3.4 km/h
  - Average reduction in mean speed = 12.4 km/h, S.D. = 3.4 km/h

While an effective device, Ewing (1999b) reports that raised tables are being promoted as an alternative device for several reasons including:

- To accommodate other agencies, such as the Fire Department.
- Being able to be extended from kerb to kerb and used as raised crosswalks. This may result in other problems, as some confusion appears to exist within the New Zealand community, as to who has the 'right of way' at raised platforms that are not marked as pedestrian crossings.

The key points are:

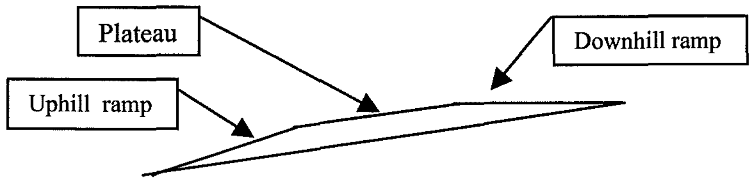
- Moderate evidence was sourced to illustrate the effectiveness of the 14 foot long humps in reducing speed, and the resultant effects.
- Raised tables are being promoted in the USA as an alternative device.

3.3.4 Raised table – Overview

In addition to the information provided in Austroads (2004), issues to consider when installing raised tables are:

- Location - Refer to section 3.3.3.
- Gradient - Webster & Layfield (1996) conducted a study, that involved in excess of 500 raised tables being installed on roads with speed limits of between 20 mph (32km/h) and 30 mph (48 km/h). They found that 172 raised tables (75/100mm high) had been installed on six roads serving as bus routes, with gradients varying between 5% and 10% without any apparent problems. DOT (1996) subsequently advised that "investigations by various local authorities suggests appropriate 'downhill' gradients of 1 in 15 for inclines of about 1 in 10, with shallower gradients (up to 1 in 35) for steeper inclines. Downhill gradients of 1 in 10 to 1 in 13 appear to be satisfactory ".

Figure 3.9 : Raised table on an incline – Cross section



(Based on DOT 1996)

- Dimensions – Raised tables 7m long (3m long plateau length and 2m long ramps with a sinusoidal profile) and 80mm high should be installed on collector streets and transit routes, except where articulated buses are used, due to decoupling (TAC 1998).
- Grounding - DOT (1996) advise that to minimise the likelihood of grounding, ramp gradients, including those at raised intersections should not be steeper than 1 in 8.

The effects are:

- Attitudes – Refer to section 3.3.3.
- Traffic volumes - Webster & Layfield (1996) found in a study of 10 schemes involving in excess of 80 x 75mm high raised tables, that volumes on these roads, changed by between +18% and – 54%, and on average reduced by 28%. The studies confirm Austroads (2004) advice.
- Pedestrian risk - No effect (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk – Refer to section 3.3.3.
- Noise - Refer to section 3.3.3.
- Vibration - no information was sourced.
- Comfort - Kennedy et al. (2004) found in a study involving 75mm high raised tables, that the peak vertical acceleration was below 0.7g for car drivers travelling at 32 km/h, and minibus/ambulances travelling at 24 km/h, and slightly above 0.7g for the bus drivers travelling at 24 km/h. The recommendation was made, that a good compromise between effectiveness and possible grounding was for the platform lengths to vary between 6 and 9m long, with ramp gradients of between 1 in 13 and 1 in 15.
- Speed - Webster & Layfield (1996) found in a study of:

- 13 schemes with 170 x 70 – 80mm high raised tables, with plateaus varying in length between 2.5 and 7m and ramp gradients varying between 1 in 10 and 1 in 15 inclusive, that the mean crossing and 85th percentile speeds was 20.6 km/h and 23.8 km/h respectively.
- 4 schemes with 23 x 100mm high speed tables, with plateaus varying in length between 6 and 10m and ramp gradients varying between 1 in 15 and 1 in 20 inclusive, that the mean crossing and 85th percentile speeds was 25.7 km/h and 33.5 km/h respectively.
- No relationship between the mean crossing speed and ramp gradient exists over the range 1 in 10 to 1 in 15, but higher speeds were found at sites with gradients of 1 in 20 or shallower.
- Ramp gradients of 1 in 15 or steeper are required at 75mm raised tables to slow traffic down.
- Plateau length appears to have minimal effect on speed, with plateaus in the range 6 - 6.5m, resulting in crossing speeds approximately 1.6 km/h faster than those with plateaus in the range 2.5 – 3.0m.

The key points are:

- Strong evidence was sourced to illustrate the effectiveness of raised tables in reducing speed and the resultant effects.
- Plateau length appears to have minimal effect on speed.
- Ramp gradients affect speed when they are shallower than 1 in 20.
- A good compromise between effectiveness and possible grounding was for the plateau lengths to vary between 6 and 9m long, with ramp gradients of between 1 in 13 and 1 in 15.

3.3.4.1 Pedestrian Platforms

LTSA (1999) defines a pedestrian platform as "a section of roadway specially textured or raised to slow vehicles and intended to provide a pedestrian crossing point for pedestrians. A pedestrian platform could be part of an intersection threshold or a mid-block treatment, and could include standard pedestrian crossing markings and signs". They come in three forms:

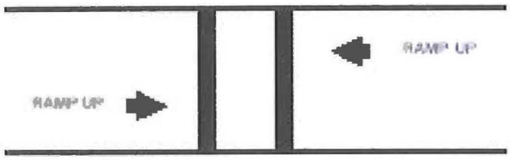
- Courtesy Crossings (New Zealand).
- Raised Crosswalks (USA).
- Wombat Crossing's (Australia).

Each is discussed in turn.

<u>Courtesy Crossings</u>
Courtesy crossings are not referred to in Austroads (2004), and are unmarked raised tables used as crossing points, and usually made of bricks or paving. No information specific to courtesy crossings could be sourced.

<u>Raised Crosswalk</u>
Raised crosswalks are not referred to in Austroads (2004). A raised crosswalk is "a marked pedestrian crosswalk at an intersection or midblock location constructed at a higher elevation than the adjacent roadway" TAC (1998), and is illustrated in Figures 3.10 and 3.11. It differs from the wombat crossing in that it is installed <u>without</u> a corresponding reduction in speed limit.

Figure 3.10: Raised crosswalk



(Source: VDOT 2002)

Figure 3.11: Raised crosswalk, Beaverton, OR

(Source: Ewing 1999b)

The effects are:

- Speed - The results of studies appear inconclusive. TAC (1998) reported reductions in the 85th percentile speeds from 54 km/h to 49 km/h at two locations, from 58 km/h to 45 km/h at one location, and no significant change in the 85th percentile speed of 42 km/h at another location. Similarly Huang & Cynecki (2001) found statistically significant reductions of 6.5 km/h in the 50th percentile speed at two sites, and a statistically insignificant reduction of 4.0 km/h in the 50th percentile speed at another site.

The key point is that limited evidence was sourced, to illustrate the effectiveness of raised crosswalks in reducing speed, and the resultant effects.

<u>Wombat Crossing</u>

Austroads (2004) defines a wombat crossing as "a flat topped raised area similar to a raised table but with the top surface marked as a designated pedestrian crossing to give priority to pedestrians". It differs from a raised crosswalk in that it is installed outside schools in conjunction <u>with</u> a permanent 40 km/h speed limit.

The effects are:

- Traffic volumes -Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Pedestrian safety - Will increase (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Noise and comfort - No information could be sourced.
- Speed - Hawley et al. (1993) found in a trial involving five sites that the 85th percentile speeds "before" speeds ranged between 53 and 69 km/h, and reduced by 30 – 50% following installation of the crossings, compared to reductions of 10 – 12% at two control sites.

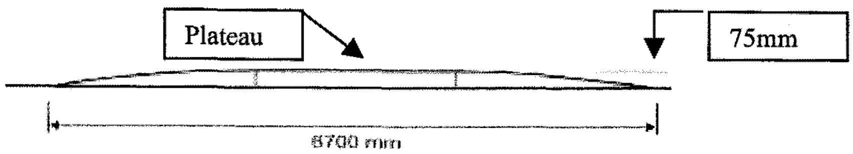
The key point is that limited information was sourced to illustrate the effectiveness of Wombat Crossings in reducing speed, and the resultant effects.

3.3.4.2 'Seminole' Speed Table

'Seminole' speed tables are not referred to in Austroads (2004) and were developed in the USA to:

- Provide a gentler ride than a Watts profile hump.
- Ensure that it could not be straddled by most single unit trucks, and minimise the likelihood of grounding, by having a 3m flat section inserted into a Watts Profile hump resulting in an overall length of 6.7m, as illustrated in Figure 3.12.

Figure 3.12: Seminole speed table – Cross section



(Source: Braaksma & Weber 2000)

The effects are:

- Traffic volumes - Ewing (1999a) found in a study involving 46 sites where 'seminole' speed tables had been installed, that volumes reduced by 12%.
- Pedestrian safety, crash risk and noise - No information could be sourced.
- Delays - Atkins & Coleman (1997) found in a study that the installation of speed tables can result in delays varying between 0 and 9.2 seconds per device, for emergency vehicles.
- Speeds - Ewing (1999a) found in a study of 58 streets where 'seminole' speed tables had been installed, that the 85^{th} percentile crossing speed was 43.4 km/h.
- Comfort – Tables 3.5 and 3.6 summarises the results of an experiment where cars and buses were driven over two 'seminole' speed tables of different heights, 75mm and 100mm.

Table 3.5: Seminole speed table (100mm high) – Peak vertical accelerations

85^{th} percentile speed (km/h)	Test Vehicle	Peak Vertical Acceleration (g)	RSS[1] acceleration (g)
40	1989 Suzuki Swift GTi	0.70	0.20
40	1997 Chevrolet Monte Carlo LS	0.62	0.18

(Source: Braaksma & Weber 2000), [1] – Root Sum Square

Table 3.6: Seminole speed table (75mm high) – Peak vertical Accelerations

85^{th} percentile speed (km/h)	Test Vehicle	Peak Vertical Acceleration (g)	RSS[1] acceleration (g)
44	1989 Suzuki Swift GTi	0.61	0.18
44	1997 Chevrolet Monte Carlo LS	0.52	0.14

(Source: Braaksma & Weber 2000), [1] – Root Sum Square

Further analysis using a multiple regression model resulted in the recommendations that:

- Humps designed for transit buses at 25 km/h, will allow cars to traverse them at 35 km/h.
- The dimensions for speed tables (including the ramps) as listed in Table 3.7 should be used, taking into account whether the road is a bus route or not.
- Additional analysis is required in the field, to determine the best compromise with regard to plateau length on routes used by buses and cars.
- Further analysis is required using different types of ramps, i.e. parabolic versus straight.

Table 3.7: Seminole speed table - Optimal speed, hump dimensions

Bus Route	Vehicle Type	Hump Crossing Speed (km/h)	Road hump dimensions (m, mm)
No	Automobile	25	5.2 x 100
No	Automobile	35	7.9 x 100
No	Automobile	45	9.1 x 75
Yes	Transit Bus	35	5.7 x 75
Yes	Transit Bus	45	Not found

(Based on Braaksma & Weber 2000)

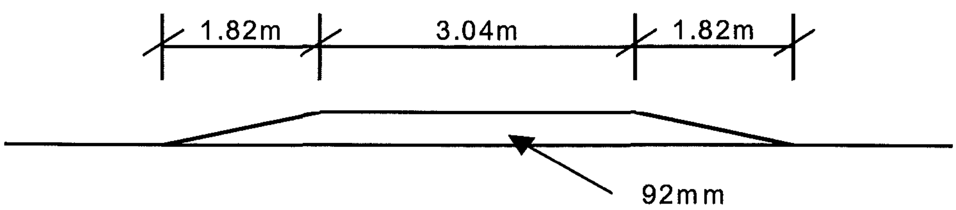
The key points are:

- Limited evidence was sourced to illustrate the effectiveness of 'seminole' speed tables in reducing speed, and particular the resultant effects.
- Difficulties in constructing a consistent profile led to the development of the 'gwinnett' profile.

3.3.4.3 'Gwinnett' Speed Table

'Gwinnett' speed tables are not referred to in Austroads (2004). "it has straight rather than curved ramps, making it trapezoidal in shape like European and British Speed Tables" (Ewing 1999b), as illustrated in Figure 3.13.

Figure 3.13: Gwinnett speed table – Cross section



(Source: County Traffic Engineer, "Standard Plan – 22' Speed Hump", Gwinett County, GA, undated)

The effects are:

- Traffic volumes - Ewing (1999a) found in a study involving 46 sites where speed tables had been installed, that volumes reduced by 12%.
- Pedestrian safety, crash risk, noise and comfort - No information could be sourced.
- Speed - Ewing (1999a) found in a study of 58 streets, that the 85th percentile crossing speed was 38.6 km/h.

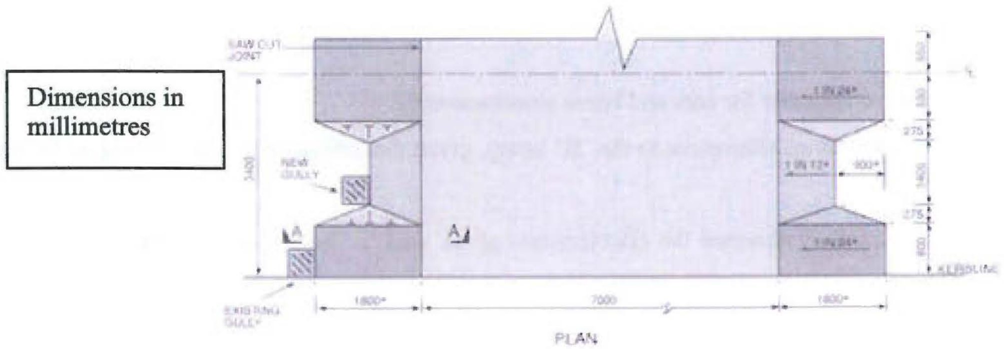
The key point is that:

- Limited evidence was sourced to illustrate the effectiveness of 'Gwinnett' speed tables in reducing speed, and in particular the resultant effects.

3.3.4.4 'H' and 'S' Humps

'H' humps are not referred to in Austroads (2004), and were developed following trials in Denmark "...showed it was possible to design a combined car and bus hump with two longer shallower outer profiles to take the tyres of buses, and with a shorter inner steeper profile to take cars" (DOT 1998b), as illustrated in Figures 3.14 and 3.15.

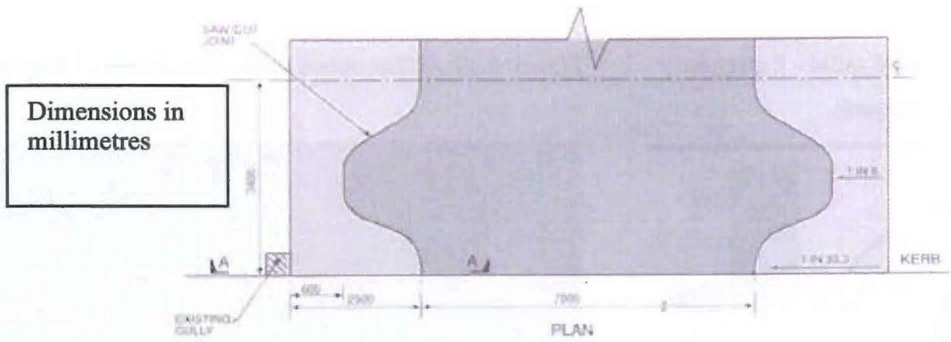
Figure 3.14: 'H' hump - Plan



(Source: DOT 1998b)

The 'S' hump was developed by Fife County Council as an alternative to the 'H' hump, given the difficulty in constructing an 'H' hump with a consistent profile.

Figure 3.15: 'S' hump - Plan



(Source: DOT 1998b)

Issues to consider when installing the humps (DOT 1998b) are:

- They should be not higher than 75mm to minimise the likelihood of grounding.
- They allow buses to use the shallower outer ramps 1 in 24 or 1 in 33 for the 'S' hump.
- They allow cars to use the steeper inner ramps, 1 in 12 or 1 in 8 for the 'S' hump.

The effects are:

- Traffic volumes, pedestrian safety, crash risk, noise and comfort - No information could be sourced.
- Speeds - DOT (1998b) reported on the results of surveys undertaken by TRL, involving two humps spaced 100m apart as listed Table 3.8.

Table 3.8: 'H' and ('S') humps – Crossing speeds

Vehicle Type	Mean speed (km/h)	85th percentile speed (km/h)	Sample size
Car	35.0 (35.2)	42.7 (42.5)	502 (504)
Goods Vehicle	32.1 (36.4)	40.2 (45.5)	12 (10)
Bus	26.2 (27.2)	34.1 (32.8)	19 (23)

(Source: DOT 1998b)

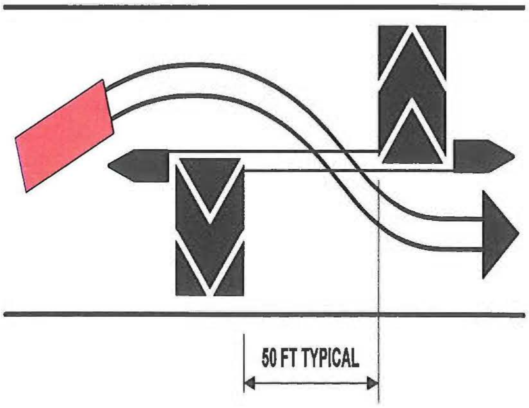
The key points are that:

- Both profiles were developed to cater for cars and buses simultaneously.
- The 'S' hump was developed as an alternative to the 'H' hump, given the difficulty in constructing a 'H' hump with a consistent profile.
- Limited evidence was sourced to illustrate the effectiveness of 'H' and 'S' humps in reducing speed, and the resultant effects.

3.3.4.5 Offset Speed Tables (USA)

Offset speed tables are not referred to in Austroads (2004) and were developed in response to the proliferation of road humps in Portland, following concern being expressed by the Fire Departments regarding the resultant delays incurred by emergency vehicles. Mulder (1998) reported on a trial using offset speed tables as an alternative device to 'Seminole' and 'Gwinnett' speed tables, that was developed further by Batson (2004). The objective of the later study was to reduce the delays at each device to approximately 2 seconds. The offset speed table, including how they are used by emergency vehicles, is illustrated in Figures 3.16 and 3.17.

Figure 3.16: Offset speed table - Emergency response path



(Source: Batson 2004)

Figure 3.17: Offset speed table, Beaverton - Oregon

(Source: Batson 2004)

Issues to consider when installing the offset speed tables (Batson 2004) are:

- They should only be used on designated routes used by emergency vehicles.
- They allow emergency vehicles to use both sides of the road and result in a loss of parking.
- They should only be installed on streets with a minimum width of 12.2m, in order to ensure that the emergency vehicles can move laterally.

The effects are:

- Traffic volumes, pedestrian safety, crash risk, noise and comfort - No information could be sourced.
- Speed - Batson (2004) reported on the effect on speeds that an offset speed table with a Seminole profile and medians had, when constructed in the summer of 2003 on a street with a 30 mph (48 km/h) speed limit, the results of which are summarised in Table 3.9.

Table 3.9: Offset speed table – Effect summary

85th percentile Speed 'Before' (km/h)	85th percentile Speed 'After' (km/h)	ADT 'Before' vpd	ADT 'After' vpd
55	48.3	5800	5400

The key points are that:

- Offset speed tables are being promoted on routes that have been 'traffic calmed' and are used regularly by emergency services.
- Limited evidence was sourced to illustrate the effectiveness of offset speed tables in reducing speed, and the resultant effects given their installation in the USA, is essentially "Work in Progress".
- It is unlikely they will be needed in New Zealand in the near future. However while traffic calming in New Zealand has primarily been restricted to local roads, recent examples exist where arterial roads have been traffic calmed, i.e.
  - Kaikorai Valley Road (Dunedin), a four lane divided arterial carrying between 10, 000 and 15,000 vpd was reduced to two lanes (one each way) in 2003. The modifications resulted in a reduction in speed and crashes, without any apparent effect on traffic volumes.
  - Creyke Road (Christchurch), discussed later in this report.

3.3.5 Road Cushions

Road cushions "were initially introduced in order to overcome concerns about discomfort and delay expressed by bus companies, and the emergency services resulting from the use of flat and round top humps" (DOT 1998a).

In addition to the information provided in Austroads (2004), issues to consider when installing road cushions are:

- Install on 'local' roads if the objective is to reduce speed, and/or reduce the volume of heavy vehicles.
- Install on routes used by emergency vehicles and buses, on the proviso that distinct differences exist between the wheel tracks of cars and heavy vehicles, such that the delays to the heavy vehicles are minimised.

- They may be inappropriate on routes used by heavy vehicles that have dual wheels, unless the objective is to discourage them from using the route (Hass-Klau et al. 1992). The Director, Technical and Operations of the Bus and Coach Council, London stated that "such humps designed to let bus front wheels through will result in heavy (over) loading of the inner rear wheels on the rear axle and a risk, particularly in wet weather, of side slipping. If the ramp is narrowed further to permit the rear twin tyres to run through the ramp at road level, there is a great risk of the rear axle casing fouling the ramp between the inner rear wheels. Ground clearances can be as low as 100mm at this point on some vehicles – even on a single deck configuration" (Hass-Klau et al. 1992).

The effects are:

- Traffic volumes - Layfield & Parry (1998) that following installation of the road cushions, traffic volumes reduced by between 2 and 48%, and on average 24%, confirming Austroads (2004) advice.
- Pedestrian safety - No effect (Austroads (2004), but no supporting data has been provided to back up the statement.
- Crash risk - Reduces (Austroads 2004), but no supporting data has been provided to back up the statement.
- Noise - Layfield & Parry (1998) reported following track trials, that for light vehicles the maximum noise levels at the cushions would reduce, reflecting lower speeds but that as the proportion of commercial vehicles increases, the reduction in traffic noise deteriorates rapidly.
- Comfort - Layfield & Parry (1998) recommended a maximum cushion width of 2000mm, reducing to between 1600 to 1700mm when installing cushions on bus routes, thereby allowing them to be straddled. Kennedy et al. (2004) found in a study of 75mm high sinusoidal, round top and flat humps, that the peak vertical acceleration was well below 0.7g for drivers and passengers travelling in all types of vehicles at speeds between 24 and 40 km/h where the cushion dimensions were: overall length including ramps, 3.0m, plateau length, 1.8m; on/off ramp gradients, overall width including ramps, 1.7m; plateau widths, 1.1m; side ramp gradients, 1 in 4.
- Driver behaviour - Layfield & Parry (1988) reported that where the cushions are unaffected by parking, 55% of cars and 90% of buses straddle the cushions, 20% of drivers drive between the cushions in paired layouts and 40% of drivers drive between the nearside and middle cushion in three abreast layouts.
- Vibration - Layfield & Parry (1998) reported that following track trials, that the wide (1900mm) cushions gave higher ground-borne vibrations than the narrower cushion, especially when heavy commercial vehicles did not straddle the cushion.
- Attitudes - Layfield and Parry (1998) reported that the level of support for the schemes following implementation, has been low, including criticism that the cushions are less effective than humps in reducing the speed of all vehicles.
- Speeds - Layfield & Parry (1998) reported on a study of 34 local authority highway authority schemes with in excess of 300 cushions, the majority of which were on roads with 30 mph (48 km/h) speed limits and on bus routes. The cushions had a maximum height of 80mm, on/off ramps not steeper than 1 in 8, and side ramp gradients not steeper than 1 in 4, and found that the:
  - Mean speeds reduced from 48.3 km/h at the cushion, to 27.8 km/h following installation of the cushions.
  - 85th percentile speeds reduced from 57.3 km/h at the cushion, to 34.9 km/h following installation of the cushions.

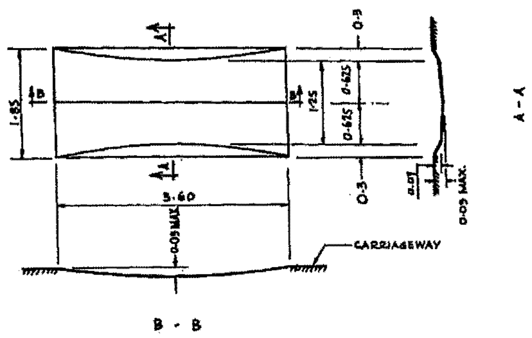
The key points are that:

- Strong evidence was sourced to illustrate the effectiveness of road cushions in reducing speed, and the resultant effects.
- Careful consideration needs to be given to the layout, as this can resulting undesirable driver behaviour, particularly in paired cushion schemes.

3.3.6 Road Depression

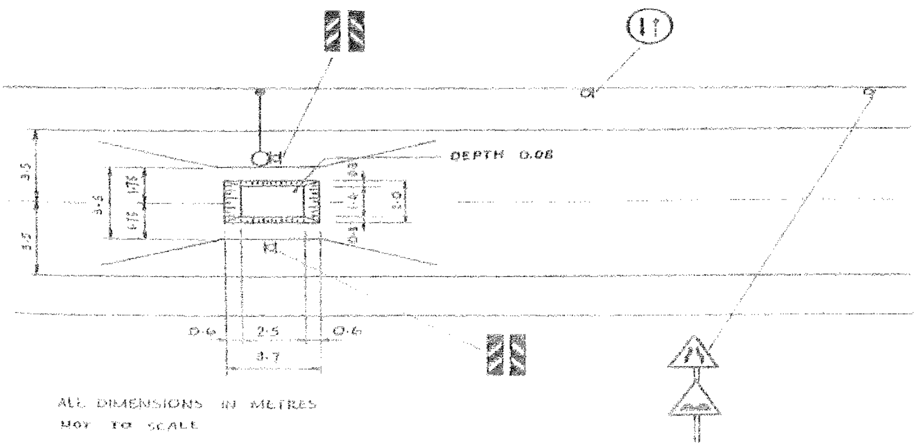
Road Depressions are not referred to in Austroads (2004) and are described as a "...sophisticated hole in the ground" Hass-Klau et al. (1992). They were developed so that buses can straddle them without the risk of grounding and cars have to drive through them.

Figure 3.18: Road depression - Plan



(Source: Stockholm Gatukontoret, 1984 cited in Hass-Klau et al. 1992)

Figure 3.19: Road depression and kerb extension - Plan



(Source: Stockholm Gatukontoret, 1984 cited in Hass-Klau et al. 1992)

Issues to consider when installing road cushions (Hass- Klau et al. 1992) are:

- Their use is restricted to Sweden.
- They can be difficult to see.
- They may not always drain and can fill up with rubbish.

The effects are:

- Traffic volumes, pedestrian safety, crash risk, noise and comfort - No information could be sourced.
- Speed - Stockholm Town Council carried out a 'before' and 'after' study on road depressions they installed at a site in Gröndalsvägen, the results which are illustrated in Table 3.10.

Table 3.10: Road depression - 'Before' and 'After' speeds

Speed of cars		**'Before'**	**'After'**	
(km/h)		Summer/Winter	Summer	Winter
At depression	Mean	40	29	30
	85th percentile	48	31	33
20m from depression	Mean	-	-	33
	85th percentile	-	-	37

(Source: Stockholm Gatukontoret, 1984 cited in Hass-Klau et al. 1992)

The mean 'after' bus speeds were:

- 34 km/h at the road depression; and
- 40 km/h 20m away from the road depression.

The key points are that:

- The depression is not a common use around the world.
- Limited evidence was sourced to illustrate the effectiveness of road depressions in reducing speed, and the resultant effects.

3.3.7 Raised Intersection Platforms

Austroads (2004) defines a raised intersection platform as, "a raised flat section of roadway extending across the apron of an intersection ramped up from the normal level of the street".

In addition to the information provided in Austroads (2004), issues to consider when installing raised intersection platforms (TAC 1998) are:

- They may be installed at sites where there are few large vehicles turning.
- The roadway approaches to and departures from the raised intersection are appropriately ramped in consideration of vehicle types and desired speed.

The effects are:

- Traffic volumes - Reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Pedestrian safety - No effect (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk – Reduces (Austroads 2004), but no supporting data has been provided to back up the statement.

- Noise and comfort - No information could be sourced.
- Speeds – Reduces (Austroads 2004), but no supporting data has been provided to back up the statement.

The key points are that:

- Limited information was sourced to illustrate the effectiveness of raised intersection platforms in reducing speed, and the resultant effects.
- As an alternative, practitioners may elect to use the information provided in Section 3.3.4.

3.4 Traffic Calming Devices – Horizontal

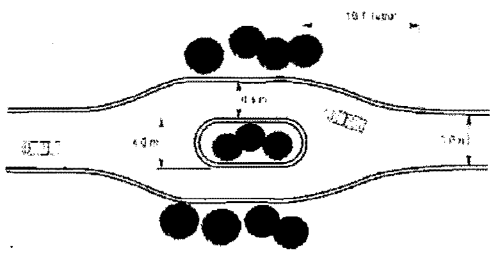
3.4.1 Background

Horizontal devices that allegedly reduce speed include centre blisters, impellors, lane narrowings, driveway links, slow points, roundabouts and mini-roundabouts.

3.4.2 Centre blisters

Austroads (2004) defines a centre blister as "a wide oval concrete island positioned at the centreline (median) of a street that narrows the lanes, diverts the angle of traffic flow, and can be used to provide pedestrians with a refuge". A similar device in use in the United States, is referred to as a speed control median (SCM).

Figure 3.20: Speed control median - Plan



(Source: Forbes & Gill 1999)

They are generally installed "when there is a need to break long lines of sight, on bus routes where raised devices and other forms of slow point are not acceptable" (Austroads 2004).

The affects are:

- Traffic volumes - Forbes & Gill (1999) reported no change in volumes, following the installation of the SCM's confirming Austroads (2004) advice.
- Pedestrian safety – Increases (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk - Forbes & Gill (1999) reported on the results of a case study, where speed control medians were installed in 1998, on an undivided two lane arterial road with a 50 km/h speed limit, and 85th percentile speeds of up to 70 km/h. At the time the paper was written, insufficient time had passed to assess the effect on the crash rate, which equated to 6.2 crashes per year over the section where the SCM's were installed.

- Noise and comfort - No information could be sourced.
- Speeds - Hawley et al. (1993) found in a study of two sites located on sub-arterial roads in New South Wales, that the 85th percentile speeds reduced by between 38% and 44% as illustrated in Table 3.11.

Table 3.11: Centre blister - 'Before' and 'After' speeds

Location	'Before'[1] 85th percentile (km/h)		'After' 85th percentile (km/h)	
	N/W	S/E	N/W	S/E
Artarmon Rd Willoughby	70	71	43	40
Flinders Rd, Bankstown	75 (mid device)		62 (mid device)	

(Source: Swinburne Ltd – Civil Eng dept 1984 cited in Hawley et al. 1993)

[1] - The 'approach' speed has been substituted for 'before' data as none was available.

Forbes & Gill (1999), reported that following the installation of the SCM's:

- The mean speed dropping by 9% from 54 to 49.3 km/h, and is statistically significant at the 99% confidence limit.
- The mean speed dropped by 3% on the control section.

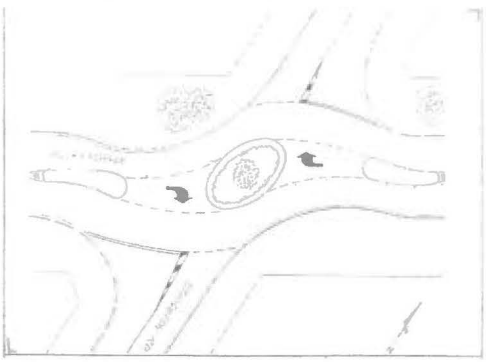
The key points are that:

- Centre blisters are generally installed to break long lines of sight, on bus routes when other forms of devices are not acceptable.
- Moderate evidence was sourced to illustrate the effectiveness of centre blisters in reducing speed, and the resultant effects.

3.4.3 Impellor

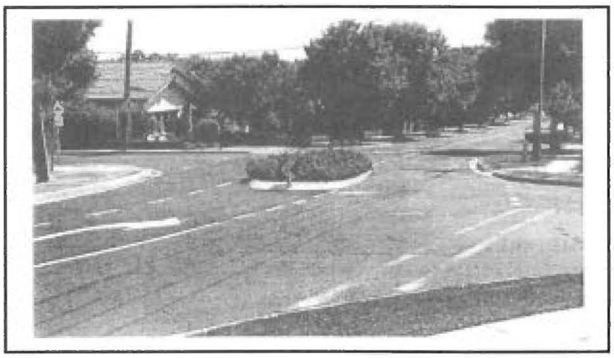
Impellors are not referred to in Austroads (2004) and are described "elliptical centre islands at intersections with a right turn bay" (Hawley et al. 1993).

Figure 3.21: Impellor - Plan



(Source: Hawley et al. 1993)

Figure 3.22: Pleasant Rd/Havelock Rd/Garden Street



(Source: Hawley et al. 1993)

They are generally installed at offset intersections with a crash history. Traffic on the side roads are controlled by stop signs, and traffic on the major road wishing to turn right , must do so prior to the island.

The effects are are:

- Traffic volumes, pedestrian safety, crash risk, noise and comfort - No information could be sourced.
- Speed - Hawley et al. (1993) found in a study of two sites in Victoria, that the 85th percentile speeds reduced by between 29% and 49% as illustrated in Table 3.12.

Table 3.12: Impellor - 'Before' and 'After' speeds

Location	'Before' 85th percentile (km/h)		'After' 85th percentile (km/h)	
	N/W	S/E	N/W	S/E
Pleasant Rd, Hawthorn	48	69	38	35
Valley Parade, Hawthorn	65	67	34	37

(Source: Swinburne Ltd – Civil Eng dept 1984 cited in Hawley et al. 1993)

The key points are that:

- They are installed primarily as a device at offset intersections with a crash history.
- Limited evidence was sourced to illustrate the effectiveness of impellors in reducing speed, and the resultant effects.

3.4.4 Lane Narrowings

Austroads (2004) defines lane narrowings as "methods to narrow the width of the road to reduce speed and pedestrian crossing distances", using for example kerb extensions, on street parking, midblock median treatments, reduced lane widths and carriageway narrowing, each of which is discussed as follows.

Kerb Extensions

Kerb extensions can be used to create pinch points. Guidance on the installation of kerb extensions follows.

- For one way traffic "The Dutch traffic calming manual (C.R.O.W. 1988) recommends for most pinch points 400-600 vehicles per hour (maximum 4,000-6,000 vehicles per 12 hours)" Hass- Klau et al. 1992. To be effective, the pinch points need traffic densities high enough to allow vehicles in opposing directions to slow each other down.
- For two way traffic, pinch points may be installed on the proviso that "...reducing the carriageway width to 4.2 – 4.4m could be used on roads with higher vehicle volumes (up to 600 vehicles per peak hour) than recommended in the Dutch manual, but only if the HGV and bus proportions are low (about 5% or less)", (C.R.O.W. 1988 cited in Hass-Klau et al. 1992).
- TAC (1998) suggests that kerb extensions are generally most effective when used in conjunction with other measures such as road humps and raised median islands.

The effects are:

- Traffic volumes – Reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Pedestrian safety - Increases (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk - Hawley et al. (1993) compared the crash rates on two sections of the same road. One section had kerb extensions installed, and marked parking lanes, whereas no changes were made to the other section. The crash rate reduced from 600 crashes per 100M VKT to 190. LTSA (1995b) reports reduction in crash rates involving pedestrians of approximately 37%, following the installation of kerb extensions. Both studies contradict the advice offered in Austroads (2004), i.e. no effect.
- Noise and comfort - no information could be sourced.
- Speeds - Several speed studies have produced conflicting results. For example, Hawley et al. (1993) found in two studies, kerb extensions were ineffective in slowing traffic. However, a number of studies reached the opposite conclusion. TAC (1998) reported that speeds had reduced by between 1 and 8 km/h on six streets in Ontario following the installation of kerb extensions, the 85th percentile speed reduced from 55 to 53 km/h on collector streets with several kerb extensions in Kitchener, and Macbeth (1995) cited in Huang & Cynecki (2001) reported speed reductions at seven midblock bulbouts where the speed limit had been reduced to 30 km/h. Huang & Cynecki (2001) found in a study of two sites, that the 50th percentile speed reduced by 1.8 km/h at treatment site (1) compared to the control site, whereas the 50th percentile speed increased at the control site relative to treatment site (2). This is contrary to the advice offered in Austroads (2004), i.e. no effect.

The key points are that:

- Limited evidence was sourced to illustrate the effectiveness of kerb extension in reducing speed given the conflicting results, and the resultant effects.
- Crash rates are likely to reduce, especially if used in conjunction with marked parking lanes or pedestrian refuges.

<u>On Street Parking</u>

Issues to consider when installing on street parking TAC (1998) are:

- It may be introduced where "the carriageway road should be at least 6m wide, to allow the installation of parking on one side of the street".
- It may be introduced where "the carriageway road should be at least 7.3m wide, to allow the installation of parking on one both sides of the street".
- It may only be introduced on local and collector residential streets with a maximum roadway width of 10m.
- It can be more effective when used in conjunction with other measures.
- It should avoid areas where parking will reduce sight distance
- It can increase the risk to cyclists.

Angle parking is not appropriate as a traffic calming measure, due to the increased potential for conflicts unless motorists reverse in. No information could be sourced on the resulting effects regarding traffic volumes, pedestrian safety, crash risk, noise and comfort.

Limited evidence was sourced to illustrate the effectiveness of on street parking in reducing speed, and the resultant effects.

Mid Block Median Treatments

Austroads (2004) defines a midblock median as "a flush or raised island placed along the centre-line of the street that narrows the carriageway, and can provide pedestrians with a safe place to take refuge". In the UK, a flush median may be referred to as a ghost island. Installing midblock medians (flush or raised) on the centreline of the road can result in a reduction in lane width, or trafficable portion of the road.

Guidance on the installation of mid block medians (DOT 1995) follows:

- Where the remaining carriageway is wider than 3.5m, the speed control effect is likely to be predominately psychological.

The effects are:

- Traffic volumes - No effect (Austroads 2004), but no supporting data has been provided to back up the statement.
- Pedestrian safety – Increases (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk – LTSA (1995b) reports reductions in crash rates involving pedestrians of approximately 18%.
- Noise and comfort - No information could be sourced.
- Speeds - Hawley et al. (1993) found that the 85th percentile speeds past a pedestrian refuge constructed in conjunction with a kerb protrusion and centreline realignment, reduced from 71 to 62 km/h. TAC (1998) reported speed reductions of between 3 km/h and 8 km/h, when mid-block medians are used in conjunction with kerb extensions. CSS/IHT (2005) reported that at a site where refuge islands were constructed in conjunction with build outs, cycle lanes and vehicle activated warning signs that speeds reduced from 53 km/h to 50 km/h. The studies confirm Austroads (2004) advice.

With respect to midblock medians limited evidence exists with respect to their effectiveness in reducing speeds, due to the small sample sets.

Reduced Lane Width

Martens et al. (1997) states that narrower lanes require more effort to stay within the lane "...since smaller lanes lead to more influence of other traffic (meeting traffic or overtaking traffic), and of obstacles along the side of the road".

Reducing lane width can be achieved by either, retaining the centre-line, remarking the edge lines, or retaining the edge lines and marking a flush median.

The effects are:

- Traffic volumes, pedestrian safety, noise and comfort - No information could be sourced.
- Crash risk - Hawley et al. (1993) reported that where 100m long painted medians were installed in conjunction with concrete islands at each end , that the number of crashes reduced from 3.5 to 1.5 per month. Other monitoring systems (LTSA, 1995b) suggest that on average, crashes reduce by 19% following installation of a flush median. The studies confirm Austroads (2004) advice.
- Speed - Several studies have shown that as lane width narrows, a reduction in driving speed usually results. Yagar & Van Aerde (1983), cited in Martens et al. (1997) found a reduction in speed of 5.7 km/h for every metre reduction in lane width beyond 4m, and Vey & Ferreri (1968) cited in Martens et al. (1997) found a higher speed for 3.4m wide lanes than for 3.0m wide lanes, on two comparable bridges in Philadelphia. However, narrower lanes do not automatically result in a reduction in speed. Van der Horst (1983) cited in Martens et al. (1997) found that speeds increased by up to 7.5 km/h, following the installing of a vehicle-free area between the two driving lanes, i.e. resulting in the lane width reducing from 4.6m to 3.6m.

The key points are that:

- Limited evidence was sourced to illustrate the effectiveness of reduced lane width in reducing speed, and the resultant effects, which appear to be influenced by how the lanes are narrowed.
- Reductions in crash risk are likely to occur.

<u>Carriageway Narrowing</u>

Hawley et al. (1993) defined "carriageway narrowing as distinct from pinch points (kerb extensions), is the reduction in carriageway width over the total length of the street to be treated".

Guidance on carriageway narrowing follows:

- It is achieved by narrowing the width of the trafficable portion of the road, over the total length of the road, by reconstructing the kerb and channel.
- It is expensive if reconstructing kerb and channel, not as part of programmed maintenance.
- It has minimal effect in reducing speeds unless travel paths are offset at regular intervals (Hawley et al. 1993).

The effects are:

- Traffic volumes, pedestrian safety, noise and comfort - No information could be sourced.
- Crash risk - Gattis (1999) found in a study of two similar roads with different widths, that the crash rate collated over a three year period was higher on the narrower roads than on the wider road.
- Speed - Numerous studies have concluded, that reducing the width of the carriageway does not automatically result in a reduction in speed. Armour (1983) cited in Brindle (1996), found that the influence of width was not as strong as street length, and that her regression equation suggested that the difference in width between a 10m and 6m road contributes to less than 1 km/h to the midpoint 85th percentile speed. Several other studies have produced similar results (Freeman 1985; Young 1987; as cited in Brindle 1996). But Bennett (1983) found on ordinary straight lengths of streets where the distance between junctions or bends was at least 200m, the mean maximum speed was about 48 km/h and below lengths of 200m, the mean maximum speed reduced with length by approximately 0.1 km/h per metre. (Womble & Bretherton 2003) established a relationship between operating speeds and straight segments of road on eight residential streets in Gwinnett County.

- $V = 16.6 + 0.03484L - 0.0000138L^2$ (Eq 1)
- $V = 85^{th}$ percentile speed (mph)
- L = length of straight residential street (ft)

The metric version of the formula is:

- $V = 26.71 + 0.1839L - 0.000239L^2$ (Eq 2)
- $V = 85^{th}$ percentile speed (km/h)
- L = length of straight residential street (m)

Table 3.13: Relationship between tangent length and operating speeds on residential streets[1]

Segment Length (m)	100	150	200	250	300
85^{th} percentile speed (km/h)	42.7	48.9	53.9	57.7	60.4

[1] – Applicable to sections of road between 300 ft (91.4m) and 1400 feet (304.8m)

The key points are:

- Strong evidence exists, illustrating the ineffectiveness of carriageway narrowing in reducing speed, as the resultant effects are based primarily on length, not width.
- Mean speeds increase steadily as the section length increases to around 200m, with the rate increasing more gradually as lengths increase beyond 200m.

3.4.5 Driveway Links

Austroads (2004) defines a driveway link as "an extended form of slow point, stretching for two or more property frontages, that provides a greater visual and physical impact on the street" than a standard slow point.

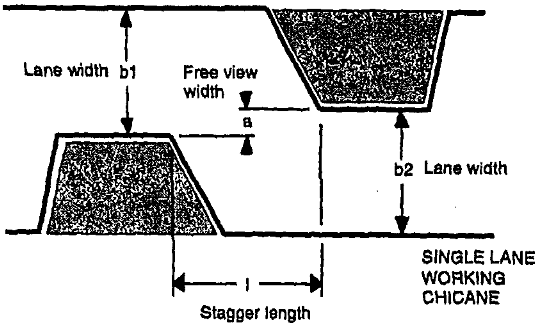
No further information could be sourced on effects (particularly speed), other than that contained in Austroads (2004).

Limited evidence was sourced illustrating the effectiveness of driveway links in reducing speed and the resultant effects.

3.4.6 Slow Points

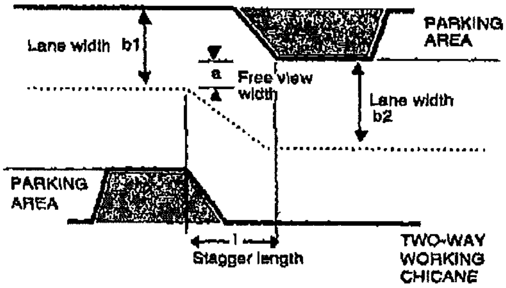
Austroads (2004) defines a slow point as "a series of kerb extensions on alternating sides of a street, that narrow and deflect the trafficable roadway - can be angled and can include a central median island or line-marking". The two main types are illustrated by Figures 3.23and 3.24.

Figure 3.23: Slow point, Single lane - Plan



(Source: Sayer et al. 1998)

Figure 3.24: Slow point, Two way - Plan



(Source: Sayer et al. 1998)

In addition to the information provided in Austroads (2004), guidance on the installation of slow points follows:

- Location:
  - In streets with a minimum of 750 vpd or 100 vehicles during peak hour otherwise the likelihood of encountering an oncoming motorist is low (TAC 1998).
  - Where the traffic volume in each direction is similar (TAC 1998).
  - On streets where the maximum posted speed limit is 50 km/h.
  - On streets with a maximum of two lanes, one in each direction.

Confrontations may occur between opposing drivers if it is not clear who has to give way, and street sweeping machines cannot sweep through the slow points.

- Gradients – On gradients not exceeding 8% (TAC 1998).

The effects are:

- Traffic volumes - Sayer et al. (1998) found that based on 13 schemes, that on average volumes reduced by 15% at single lane slow points, and 7% at two way slow points. The studies confirm Austroads (2004) advice.
- Pedestrian safety - No effect (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk - Sayer et al. (1998) found that based on 17 schemes, there was an overall reduction in accident frequency of 54%, but highlighted concerns expressed by cyclists about being overtaken within the slow points. Cycle bypasses are recommended at sites with high traffic volumes. This is contrary to the advice in Austroads (2004), i.e. no effect.
- Noise and comfort - No information could be sourced.
- Speed - Sayer et al. (1998) reported on a study involving 49 schemes with 142 slow points, the results of which are summarised in the Tables 3.14 and 3.15.

Table 3.14: Single lane slow points (10 schemes) – 'Before' and 'After' speeds

Mean speed (km/h) 'at'			85th percentile (km/h) 'at'			"a" value (m)	'l' value (m)	Avg lane width	'path angle' (degrees)
'Before'	'After'	Diff	'Before'	'After'	Diff				
55.2	34.0	21.2	63.1	41.8	21.3	1.4	11.6	4.1	13.4

(Based on Sayer et al. 1998)

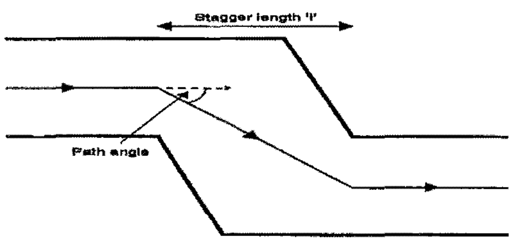
Table 3.15: Two way Slow Points (6 schemes) – 'Before' and 'After' speeds

Mean speed (km/h) 'at'			85th percentile (km/h) 'at'			"a" value (m)	'l' value (m)	Avg lane width	'path angle' (degrees)
'Before'	'After'	Diff	'Before'	'After'	Diff				
61.0	42.6	18.4	67.4	50.4	17.0	1.0	13.9	3.1	8.9

(Based on Sayer et al. 1998)

An inverse relationship exists between the path angle and the mean and 85th percentile speeds 'at' the slow point. The greater the path angle, the lower the speed (Figures 3.25 to 3.27).

Figure 3.25: Slow Point - 'path angle' definition

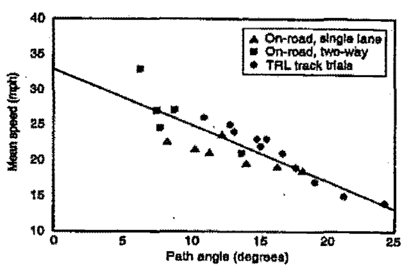


(Source: Sayer et al. 1998)

The path angle is calculated as follows:

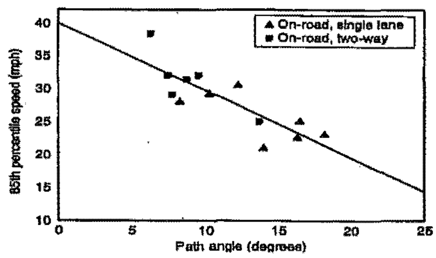
$$\text{Path Tan}^{-1} = \frac{(b1 + b2)/2 - a}{L}$$

Figure 3.26: Slow point - Mean speed vs path angle



(Source: Sayer et al. 1998)

Figure 3.27: Slow point - 85th percentile speed vs path angle



(Source: Sayer et al. 1998)

In general, path angles of greater than 15° should reduce speeds at slow points to a mean value of less than 20 mph (32.2 km/h). Path angles of about 10°, can be expected to result in 85th speeds in excess of 30 mph (48.3 km/h), whereas path angles of 15 to 20° are likely to result in 85th percentile speeds between 20 mph (32.2km/h) and 25 mph (40.2 km/h).

The studies confirm Austroads (2004) advice.

The key points are that:

- Strong evidence was sourced illustrating the effectiveness of slow points in reducing speed, and the resultant effects.
- Care obviously needs to be taken on high volume routes used by cyclists, although high volume roads have not been defined.

3.4.7 Roundabouts

Austroads (2004) defines a roundabout as "a channelised intersection, at which all traffic moves clockwise around a central traffic island, which simplifies the allocation of priority". Their secondary objective is to reduce speed, and they should be installed in conjunction with other traffic calming devices.

The effects are:

- Traffic volumes - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Pedestrian safety - No effect (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Noise and comfort - No information could be sourced.
- Speeds - Several studies (Lynam 1987; Schull & Lang; Davies 1988) cited in Martens et al. 1997 found that roundabouts were successful at reducing vehicle speeds, and breaking up the perceived straightness of the road. Klyne (1998) found that the 95th percentile operating speed through a single lane roundabout, can be determined by the empirical formula.

  $$V = 6\,R^{1/2} \qquad \text{(Eq 3)}$$

  Where:
  V = 95th percentile operating speed (km/h)
  R = Radius (m) of centre-line of 2m wide vehicle path (touching both kerbs and the central island).

  Furthermore, Klyne (1998) reported on a case study where markings were painted around the central island of roundabouts at four sites, to artificially increase the size of the island, and to reduce the perceived carriageway width. The markings in the configuration of chevron arrows were painted 400 to 500mm wide, offset 150mm from the kerb.

The 85th percentile speeds reduced by between 2.65 and 4.01 km/h following installation of the markings.

Figure 3.28: Edge Line marking around roundabout

(Source: Klyne 1998)

The studies confirm Austroads (2004) advice.

The key points are that:

- Roundabouts secondary objective is to reduce speed.
- The effectiveness of the paint markings in reducing speeds and resultant effects are limited with respect to retrofitting roundabouts, as the findings are based on one case study. The treatment may have some use in retrofitting some roundabouts where speed is a problem, however, it is unlikely to be a substitute for good geometric design.

3.4.8 Mini- roundabout

A mini-roundabout differs from a roundabout in that the latter are larger, have raised median islands on all approaches, and in some cases, the entry is flared to two or more lanes.

The effects are:

- Traffic volumes - In some cases volumes have increased, but in general they have reduced (TAC 1998).
- Pedestrian safety - No information could be sourced.
- Crash risk - Will reduce (TAC 1998). Other studies have reached similar conclusions (NVF 1984; Hyden et al. 1995; Seim 1991; Simon 1991; Van Minnen 1992) cited in Martens et al. (1997).
- Delays - Additional delays may be imposed on emergency vehicles varying between 1.3 – 10.7 seconds per circle (Atkins & Coleman 1997).
- Noise and comfort - No information could be sourced.
- Speeds - Varhelyi (1993) cited in Martens et al. (1997) reported on an experiment with mini-roundabouts used as a speed reducing measure in a Swedish town, that the mean speed reduced from 48 km/h to 35 km/h, not only at the intersections, but on the links between them. Typically the 85th percentile speeds of 58 km/h, reduced to 44 km/h following installation of a mini-roundabout (TAC 1998).

The key point is that limited evidence exists on the effects of installing mini-roundabouts.

3.5 Traffic Calming Devices - Signage, Line Marking & Other Treatments

3.5.1 Background

Signage, line marking & other treatments that allegedly reduce speed include give way signs, pedestrian crossings, perimeter threshold treatments, shared zones, speed limit signs, stop signs, tactile surface treatments and road markings. Each device is discussed in turn, noting that no further information could be sourced on the installation and effects relating to give way signs, markings and pedestrian crossings.

3.5.2 Perimeter threshold treatments (entry statement, gateway or threshold treatment)

Austroads (2004) defines a perimeter threshold treatment as "a coloured and/or textured pavement surface that contrasts with the adjacent road alerting drivers they are entering a local traffic area". They are generally installed "...to alert drivers they are entering a driving environment that is different from the one they have just left by the use of visual and/or tactile clues" (Austroads (2004).

In addition to the information provided in Austroads (2004), issues to consider when installing perimeter threshold treatments are:

- To achieve the most beneficial effect, other traffic calming features will have to located close to the gateway, and extend over the length of the road over which speeds need to be constrained (DOT 1993b).

The effects are:

- Traffic volumes - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Pedestrian safety - No effect (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Noise and comfort - No information could be sourced.
- Speeds - DOT (1993b) cites Wheeler (1993), indicating that speed reductions up to 10 km/h can be attained, and where they have been achieved they have not been sustained over any distance, and speeds at the most have been reduced by 3.2 km/h, confirming Austroads (2004) advice.

The key points are that:

- Strong evidence was sourced regarding the effectiveness of perimeter threshold treatments in reducing speed, and the resultant effects on the proviso that careful consideration is given to their design.
- They should supplement other traffic calming devices.

3.5.3 Shared Zones

Austroads (2004) defines a shared zone as "very low speed streets with vehicles, pedestrians and other road users sharing the same space".

In addition to the information provided in Austroads (2004), issues to consider when installing shared zones (Hawley et al. 1993) are:

- 10 km/h speed restriction signs must be installed at the entry to each end of the zone, thereby supplementing physical measures.
- Shared zones are suitable for streets with less than 300 vpd.

The effects are:

- Traffic volumes - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Pedestrian safety - Will increase (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk - No effect (Austroads 2004), but no supporting data has been provided to back up the statement.
- Noise and comfort - No information could be sourced.
- Speeds - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.

There are only a small number of shared zones in NSW, all in the Sydney Metropolitan Area (Hawley et al. 1993).

The key point is that limited evidence was sourced regarding the effectiveness of shared zones in reducing speed and the resultant effects. The lack of widespread implementation, suggests that other effects (such as community attitudes or legislation) may govern the decision on whether to install them or not in Australasia.

3.5.4 Speed Limit Signs

Austroads (2004) defines speed limit signs as "signs displaying reduced speed limits. May be implemented on an area wide basis".

The purpose of a speed limit sign, is to inform drivers of the maximum legal speed limit and are generally installed where the proposed speed limit is compatible with the street speed environment. The signs are a passive device, and can require regular police enforcement to ensure compliance.

The effects are:

- Traffic volumes - No effect (Austroads 2004), but no supporting data has been provided to back up the statement.
- Pedestrian safety - Will increase (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Noise and comfort – No effect (Austroads 2004), but no supporting data has been provided to back up the statement.
- Speeds - Some studies have found that installing signs on their own is ineffective in reducing speeds. For example Hawley et al (1993) found in a trial undertaken in North Fremantle that involved reducing the speed limit from 60 km/h to 40 km/h that the:
  - Mean speeds <u>increased</u> (statistically significant).

- 85^{th} percentile speeds decreased (not significant).
- Signage alone was not successful in ensuring motorists complied with the acceptable maximum speeds.

TAC (1998) found that reducing the maximum posted legal in Boulder from 48 km/h to 40 km/h, resulted in changes in vehicle speeds, ranging from reductions of up to 2 km/h, to increases up to 3 km/h. Mackie (1998) reported on a review of studies of the effectiveness of attempts to manage speeds in urban areas and concluded that:

- Static (speed limit) signs were effective in reducing the mean speed, and the 85^{th} percentile speeds by approximately 3 km/h.
- The most effective measures for controlling speed are physical traffic calming measures.

The key points are that:

- Limited evidence was sourced regarding the effectiveness of speed limit signs in reducing speed, and the resultant effects.
- Speed limit signs should be supplemented by physical measures.

3.5.5 Stop Signs

Austroads (2004) defines a stop sign as a "sign informing road users to stop at an intersection". Stop signs that are generally installed at locations other than where visibility is restricted, may result in a high level of non-compliance.

The effects are:

- Traffic volumes - TAC (1998) reported an average reduction in daily traffic volume from 2700 vpd to 2000 vpd, following installation of three all way stops in series, confirming Austroads (2004) advice.
- Pedestrian safety - Noyes (1994) suggested that pedestrian safety will decrease as a result of an increase in exposure time, a result of lower approach/departure speeds, and due to the low percentage (7 - 40%) of motorists observed stopping during a study. This is contrary to Austroads (2004) advising that pedestrian safety will increase.
- Crash risk - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Speeds - Noyes (1994) found in a study, that involved measuring the speeds of 100 vehicles as they approached and departed from six intersections with stop signs on all approaches, that the speeds 152m from each of the six intersections is similar to the street speeds illustrated in Table 3.16.

Table 3.16: Multiway stop signs - Speed result summary

Speed Limit (km/h)	152m prior to Stop Sign (km/h)		152 downstream from the Stop Sign (km/h)		Street Speeds (km/h)	
	Mean	85^{th} percentile	Mean	85^{th} percentile	Mean	85^{th} percentile
48	50	56	48	55	51	58
40					48	55

(Based on Noyes 1994)

Similar results were found by Cline (1997) cited in Clarke (2000). Clarke (2000) found in a study of two streets with two and four way stops, where speeds were measured at the intersections, midblock, 10.7m and 45.7m from the intersections, that the signs affected speeds of vehicles within 30.5m of the intersection. The studies confirm Austroads (2004) advice.

The key points are that:

- Strong evidence was sourced regarding the ineffectiveness of <u>all way</u> stop signs in reducing speed, and the resultant effects.
- The effect on speeds is limited to an area in close proximity to the intersection.

3.5.6 Tactile Surface Treatments, Textured Pavements, Transverse Rumble Strips

Austroads (2004) defines tactile surface treatments, textured pavements, transverse rumble strips as "low bumps, buttons, bars, grooves or strips closely spaced across, or immediately adjacent to a street or path that draw attention to a feature or hazard, and can have a vibratory and/or audible effect when travelled over".

Martens et al. (1997) describes that "the effect on driving speed is not the result of the roughness of the road surface per se, but rather an effect of a reduction in driver comfort".

The effects are:

- Traffic volumes - No effect (Austroads 2004), but no supporting data has been provided to back up the statement.
- Pedestrian safety - No effect (Austroads 2004), but no supporting data has been provided to back up the statement
- Comfort - No information could be sourced.
- Vibration, 67% of drivers noticed the vibration, and 77% of drivers were alerted by the device (Sumner & Shippey 1977 cited in Webster & Layfield 1993).
- Speeds – Reduce (Austroads 2004), but no supporting data has been provided to back up the statement

Each device is discussed in turn regarding its effectiveness in reducing speed.

<u>Transverse Rumble Strips</u>

The effects are:

- Noise - Webster & Layfield (1993) reported that roadside noise levels increased by up to 6dB(A), following the installation of rumble strips, and that some county authorities recommend that rumble devices are not installed within 250m of any residential dwelling.
- Crash risk - Several studies have found reductions in accidents following the installation of rumble strips (-39%, Sumner and Shippey 1977 cited in Webster & Layfield 1993; -28%, Webster & Layfield 1993). Neither study was statistically significant. This is contrary to the advice offered in Austroads (2004), i.e. no effect.
- Speeds - A number of studies have found that rumble strips reduce speeds (Zaidel, Hakkert and Barkan 1986; Kermit & Hein 1962 cited in Martens et al. 1997). Webster & Layfield (1993) found in a study of 35 sites in the UK that:

- The average 85th percentile speed reduced by 2.3 mph (3.7 km/h), excluding those sites removed within 3 months of installation
- At sites with widely spaced groups of strips, drivers reduced their speed as they approached the strips, but returned to their previous speeds between groups.
- No one type of layout and dimensions seemed to be significantly better than others in terms of speed reduction, within the general principle of bands of coarse surface texture, or two or more groups of 10 to 13mm strips spaced at decreasing intervals as the hazard is approached.
- The final band or group of strips should be sited as close as possible to the hazard as practical, typically 50m, because the reducing effect of the rumble devices on vehicle speeds, decreases as the distance from the last rumble device increases.

Not all studies have found a reduction in speed. TAC (1998) reported that speeds reduced by 5 km/h at one site, and had no significant effect on vehicle speeds at sites in Phoenix, given changes in speeds varied between a 5 km/h reduction to an 8 km/h increase. Other studies (Cheng, Gonzalez & Christensen 1994; Seco 1997 cited in Martens et al. 1997) found that there were no reduction in speeds, when transverse rumble strips were installed in close proximity to a pedestrian crossing.

They key points are that:

- Their primary purpose is to alert drivers to a hazard and should supplement traffic calming devices.
- Limited evidence was sourced regarding the effectiveness of transverse rumble strips in reducing speed, and the resultant effects given the conflicting results from different studies.
- Care needs to be taken when installing them in close proximity to residential dwellings.

Transverse Road Markings

Transverse marking patterns can decrease speed, as they give the motorist the illusion that they are driving faster than they are. The markings are suitable for use in reducing speeds on the approach to a dangerous site, for example a roundabout or bend.

Fildes, Fletcher & Corrigan (1987) cited in Martens et al. (1997) found that the use of herringbone markings along the side of the road, that increase in frequency while approaching a dangerous location, led to a reduction in mean driving speed. Similar results were found in other studies (Denton 1971, 1973; Rockwell & Hungerford 1979; Agent 1980 cited in Martens et al. 1997). There is, however, some uncertainty with respect to the durability of speed reductions. Havell (1983) cited in Martens et al. (1997) suggested that the effectiveness of measures can be maintained for months, while others Maroney & Dewar (1987) cited in Martens et al. (1997) suggested that the benefits fade in a matter of days or weeks.

The key points are:

- Transverse road markings primary purpose is to alert drivers to a hazard.
- Strong evidence was sourced regarding the effectiveness of transverse road markings in reducing speed, and the resultant effects, although some doubt exists with regarding their long term effectiveness.

Roughness of Road Surface

Several studies have investigated the effect of surface roughness on driving speed:

- Cooper, Jordan & Young (1980) cited in Martens et al. (1997) found increases in speed, of up to 2.6 km/h after resurfacing three test sites, where the profile of the surface was improved.
- Te Velde (1985) cited in Martens et al. (1997) found that if a smooth road surface was followed by a rough surface, this resulted in a mean reduction in speed of 5%, and that there was no immediate reduction in speed if a rough surface was followed by a smooth road surface.

Not all studies have found that speeds have reduced as a result of a rough surface, for example Michels & Van Der Heijden (1978) cited in Martens et al. (1997) suggested that other characteristics in the study may well have influenced the speed behaviour.

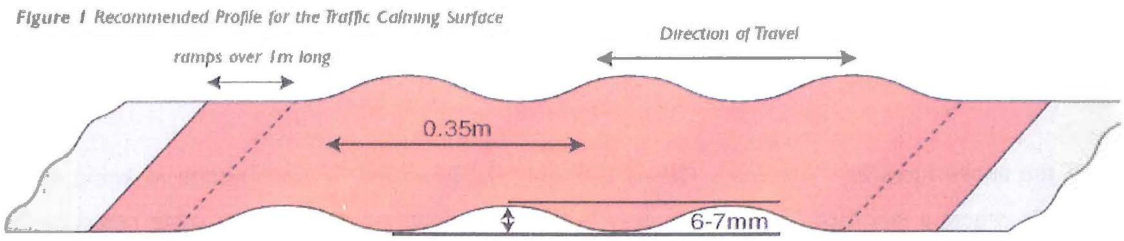
Limited evidence was sourced regarding the effectiveness of road roughness in reducing speed, and the resultant effects.

Rumble-wave

Rumblewave surfacing is not referred to in Austroads (2004), and was developed as a quieter alternative to conventional rumble strips such that it could be used in residential areas, creating noise and vibration within vehicles passing over it, without increasing noise levels significantly for those outside vehicles. It has been piloted at seven sites, with speed limits varying between 20 mph (32 km/h) and 30 mph (48 km/h), and at thresholds where the speed limit reduces from 60 mph (96 km/h) to 40 mph (64 km/h), with traffic volumes up to 21,500 vpd (DOT 2005). DOT (2005) recommends that the 'rumble-wave" surfacing is not used in areas where 85th percentile speeds are greater than 45 mph (72 km/h), as no systematic testing has been carried out at speeds exceeding this. Where there are higher speeds, traffic calming measures should be implemented first to reduce the speeds to below 45 mph..

The surface comprises hot rolled asphalt, laid in a sinusoidal profile (Figure 3.29).

Figure 3.29: Rumblewave - Recommended profile



(Source : DOT 2005)

Issues to consider when installing rumble wave surfacing (DOT 2005) are:

- Use as an alerting feature, in advance of hazards or junctions.
- It should be installed across the entire carriageway.
- It should be installed at least 30m from the nearest house foundations, to avoid noise and vibration problems.

- It should be installed in conjunction with other traffic calming devices when seeking to reduce speeds.
- It should not be used at pedestrian crossing points, as it could act as a trip hazard.

The effects (DOT 2005) are:

- Cyclists - A smoother strip of the material is provided, tapering from a profiled to smooth surface finish across its width to avoid any vertical up-stand in the area used by cyclists.
- Noise - Recorded external noise levels did not change greatly.
- Speeds - Mean speeds reduced by between 0.2 mph (0.3 km/h) and 1.9 mph (3.1 km/h) at seven pilot sites, where the 'before' mean speeds ranged between 26.8 mph (43.1 km/h) and 37.1 mph (59.7 km/h). The 85th percentile speeds showed similar reductions, although one site recording an increase of 0.4 mph (0.6 km/h).
- Accidents - Monitoring of sites shows a reduction in the crash rate of 55%, statistically insignificant since the analysis period is less than 3 years.

The key points are:

- Rumblewave can be used as an alerting feature in advance of hazards or junctions.
- Minimal changes in external recorded noise have been recorded following the installation of rumblewave.
- Limited evidence was sourced regarding the effectiveness of rumblewave surfacing in reducing speed, and the resultant effects given it has been trialed at a few sites.

3.6 Traffic Calming Devices - Diversion/Obstructive

Diversion devices are used to redirect traffic, typically through the use of physical obstructions in the roadway, supplemented by regulatory signs. These measures are located typically at intersections and midblock locations, and aim to discourage through traffic, which may reduce conflicts and vehicle speeds. Five devices that are commonly used in LATM schemes are:

- Full road closures.
- Half road closures.
- Diagonal road closures.
- Modified 'T' intersections.
- Left-in/out islands.

Of the above measures, Austroads (2004) lists only the Modified 'T' intersection as being effective in reducing speeds, where a modified 'T' intersection is "a three-way intersection treatment using raised medians, signage and other delineation to modify the priority and to slow and physically direct traffic through an intersection".

The effects are:

- Traffic volumes - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.
- Pedestrian safety - Will increase (Austroads 2004), but no supporting data has been provided to back up the statement.
- Crash risk - Will reduce (Austroads 2004), but no supporting data has been provided to back up the statement.

- Noise and comfort - No information could be sourced.
- Speeds - Hawley et al. (1993) reported that the effectiveness of the device in speed control, is directly related to the angle of deflection caused by a protuberance and the lane width. In trials in Willoughby (NSW), a T-deviation device with a minor deflection was found to be less successful, than road humps and platforms from a performance and community acceptance perspective. This contrary to Austroads (2004) advice.

The key points are:

- The effectiveness of modified 'T' intersections in speed control is directly related to the angle of deflection.
- Limited evidence was sourced regarding the effectiveness of modified "T" intersections in reducing speed, and the resultant effects. The design philosophy for slow points may assist in addressing this issue.

3.7 Traffic Calming Devices - Summary

The effectiveness of all devices (vertical, horizontal, signage, line marking, other treatments and diversion/ obstructive) is summarised in Table 3.17. The table ranks each device based on the evidence sourced from the literature review as per Table 2.1), listing the key effects, indicative 'after' speeds, and key points that practitioners should note.

Table 3.17: Device Summary including indicative effects

Device	Effect on Speed			Mean 'After' (km/h)[1]	85th %ile 'After' (km/h)[1]	Reduce Vol.	Increase Ped. Safety	Reduce Crash Risk	Notes
	S	M	L						
Road bump	Yes			35	45	-23%		No	Ineffective in reducing speed, and they have been replaced with better designed, and more functional humps. They increase the risk of crashes occuring, particularly for motor cyclisits.
Hump, general	-	-	-			-24% (average)	Yes	-65% injury	Can be installed on gradients of up to 8%. The maximum height should not exceed 75mm in order to reduce the risk of grounding.
Hump, sinusoidal			Yes	24.9					Generally used on local roads, specifcially catering for cyclists
Hump, 100mm high circular	Yes			22					The abruptness of the hump results in the peak vertical acceleration approaching 0.7g, and the potential grounding of vehicles due to the height, has lead to the development of lower profiles.
Hump, 75mm high circular	Yes			23.7	30.6				Peak vertical acceleration is below 0.7g for cars crossing at 32.2 km/h. Results in reductions in noise, of up to 4dB(A) at and between humps.
Hump, 12 foot long	Yes				24 - 32	-18%			The parabolic profile is difficult to replicate. The hump was developed in North America in response to the Watts profile hump being perceived as to abrupt, and the crossing speeds being unrealistically low. 100mm high, 12 foot long humps out of favour as they are too abrupt.
Hump, 14 foot long		Yes			See notes	-22%			The parabolic profile is difficult to replicate. The hump was developed as an alternative to the 12 foot long hump, which is too abrupt, with a maximum height of 75mm. The 85th percentile speeds are approximately 5 km/h greater than 12 foot long humps.
Raised table, general	-	-	-	20.6[2] (25.7)[3]	23.8[2] (33.5)[3]	-28% (average)	-	-65% injury	The Peak vertical acceleration is below 0.7g for cars crossing at 32.2 km/h. The 75mm high raised table was developed for use on truck and bus routes and can be used on road gradients up to 8%. Noise reductions of up to 4Bd(a) at 75mm high raised tables and between, have been recorded. A raised table with a plateau 6-9m long, and ramps with gradients between 1 in 13 and 1 in 15 is a good compromise between grounding and effectiveness. The plateau length has minimal effect on crossing speeds.
- Courtesy crossing			Yes				Yes		
- Raised crosswalk			Yes				Yes		

S – Strong, M – Moderate, L - limited, [1] – At device, [2] – 70/80 mm high, [3] – 100mm high

Table 3.17 (cont.): Device Summary including indicative effects

Device	Effect on Speed			Mean 'After' (km/h)[1]	85th %ile 'After' (km/h)[1]	Reduce Vol.	Increase Ped. Safety	Reduce Crash Risk	Notes
	S	M	L						
- Wombat crossing			Yes		See notes	Yes	Yes	Yes	Wombat crossings duffer from a raised crosswalk, by having a permanent 40 km/h speed limit installed. Speeds reduced by 30 to 50%
- 'Seminole' speed table			Yes		43.4	-12%			The peak vertical accelerations varied between 0.62 – 0.7g and 0.52 – 0.61g for cars crossng 100mm and 75mm high tables respectively. They were ddeveloped as an alternative to the Watts profile hump. Delays to emergency vehicles up to 9.2 s/ device may be incurred. Optimal dimensions to balance speeds and comfort for cars/buses still being investigated. Problems exist with producing a consistent curve ramp profile.
- 'Gwinnett' speed table			Yes		38.6	-12%			The 'Gwinnett' was developed as an alternative to the Seminole speed table, and built with straight ramps. Optimal dimensions to balance speeds and comfort for cars/buses still being investigated. The maximum height should not exceed 75mm in order to minimise the likelihood of grounding.
- 'H' hump			Yes	35.0	42.7				A combined hump catering simultaneously for buses and cars. The profile is difficult to replicate consistently. The maximum height should not exceed 75mm in order to minimise the likelihood of grounding.
- 'S' hump			Yes	35.2	42.5				Developed in the UK as an alternative to the 'H' hump with straight ramps.
- Offset speed table			Yes		48.3	See notes			Delays to emergency vehicles up to 2.0s per devices may be incurred. Minimal change in traffic volume.
Road cushions	Yes			27.8	34.9	-24% (average)		-65% injury	Peak vertical accelerations are well below 0.7g for driver and passenger in most vehicles. Compliance problems can exist with incorrectly designed cushions. Community attitudes suggest a low level of public support relative to road humps.
Road depression			Yes	29 - 30	31 -33				Mean bus speeds were at the depression. Use appears restricted to Sweden.
Raised intersection platform			Yes			Yes	-	Yes	Refer to raised tables for design parameters.
Centre blisters		Yes			See notes	Varies	Yes	-	Generally installed on bus routes when other devices are unacceptable and to break long lines of sight. Speeds reduce by between 38 and 44%.
S – Strong, M – Moderate, L - Limited, [1] – At device									

Table 3.17 (cont.): Device Summary including indicative effects

Device	Effect on Speed			Mean 'After' (km/h)[1]	85th %ile 'After' (km/h)[1]	Reduce Vol.	Increase Ped. safety	Reduce Crash Risk	Notes
	S	M	L						
Impellor			Yes		34 - 38			Yes	The primary purpose is to install impellors at offset intersections with a crash history. Speeds reduced by between 29 and 44%.
Kerb extension			Yes			Yes	Yes	See notes	Kerb extensions are effective in reducing crash risk if they are used in conjunction with marked parking lanes or pedestrian refuges. Conflicting results exist regarding their effectiveness in reducing speeds.
On street parking			Yes					See notes	Angle parking can increase the risk to cyclists.
Midblock median			Yes		See notes	-	Yes	-18%	Speeds reduce by up to 8km/h when mid block medians are used in conjunction with kerb extensions.
Reduced lane width			Yes		See notes			Yes	Conflicting results exist on the effectiveness of lane narrowing in reducing speed, which is dependent on how the lane narrowing is achieved, i.e. narrower lanes appear to result in reduced speeds, except when lanes are narrowed in conjunction with installing a flush median, where speeds may increase by up to 7.5 km/h.
Carriageway narrowing	Yes							Increase	Carriageway narrowing is generally undertaken in conjunction with programmed kerb and channel renewal over the entire length of the street, and where the 85th percentile speed > 65 km/h. The key parameter in reducing speeds along residential streets is <u>length</u> not width.
Driveway links			Yes			Yes	Yes	-	
Slow point – single lane	Yes			34.0	41.8	-15%		See notes	The accident frequency reduces by up to 54%. Single lane slow points can increase the risk to cyclists, if they are overaken within the slow point.
Slow point - two way	Yes			42.6	50.4	-7%		See notes	The accident frequency reduces by up to 54%.
Roundabouts		Yes			See notes	Yes	-	Yes	Rounadbouts secondary objective is to reduce speed, and the 95th %ile operating speed through the roundabout can be determined by Klyne's formula.

S – Strong, M – Moderate, L – Limited, [1] – At device

Table 3.17 (cont.): Device Summary including indicative effects

Device	Effect on Speed			Mean 'After' (km/h)[1]	85^{th} %ile 'After' (km/h)[1]	Reduce Vol.	Increase Ped. Safety	Reduce Crash Risk	Notes
	S	M	L						
Mini-roundabouts			Yes		44.0	See notes	-	See notes	Generally the crash risk reduces, although conflicting results have been recorded. Additional delays of up to 10.7 seconds per vehicle may be imposed on emregency vehicles.
Give way signs			Yes			Yes	Yes	Yes	-
Pedestrian crossings			Yes			-	Yes	Yes	-
Perimeter threshold treatments	Yes				See notes	Yes	-	Yes	Some studies have suggested that reductions of 3.2 km/h are typical, and perimeter threshold treatments are ineffective unless supplemented by other devices.
Shared zones			Yes			Yes	Yes	-	Shared zones have not been widely implemented in Australia.
Speed limit signs			Yes			-	Yes	Yes	Mackie (1998) suggested that a maximum reduction of 3 km/h in the mean and 85^{th} percentile speeds followiong the installation of speed limit signs is 'typical'.
Stop signs			Yes			Yes	Yes	Yes	The reduction in speed at intersections with all way stops, is limited to within 30.5m of the intersection.
Tactile surface treatments - general						-	Yes	Yes	Tactile surface treatments are generally installed as an alerting device. Vibration and noise are issues noticed by the public.
- Transverse rumble strips			Yes		See notes			Yes	Roadside noise levels increased up to 6dB(A). Studies have produced conflicting results regarding the effectiveness of the device in reducing speed. Care needs to be taken when installing transverse rumnle strips close to residential dwellings.
- Transverse road markings	Yes				See notes				The primary purpose of transverse ropad markings is to alert drivers to the presence of a hazard. Studies have produced conflicting results regarding the effectiveness of the device in reducing speed, and the durability of the speed reduction.
- Road roughness			Yes		See notes				Studies have produced conflicting results regarding the effectiveness of the device in reducing speed.
- Rumblewave			Yes	See notes	See notes				Rumblewave is a relatively new device, which following filed trials at seven sites resulted in speed reductions of up to 3.1 km/h, in the mean and 85^{th} percentile speeds. Minimal changes in external noise levels have been recorded following installation.
Modified 'T' intersections			Yes		See notes	Yes	Yes	Yes	The effectivess of the device is related to the angle of deflection.

S – Strong, M – Moderate, L - Limited, [1] – At device

3.8 Traffic Calming Devices - Spacing

3.8.1 Background

Austroads (2004) states that "the objective of speed management techniques in LATM is to attain target street speeds within acceptable speed differential limits". The process is outlined, requiring a knowledge of the devices crossing speed, 'between' device speed profiles, and suggests that the upper limit to the speed differential for planning and design purposes is 20 km/h. Austroads (2004) provides guidance on spacings if no local data is available including the following table.

Table 3.18: Slow points - Intermediate speeds as a function of device separation

Distance between slow points (m)	40	75	100	120	140	155
Max. 85th percentile speed between slow points[1] (km/h)	25	30	35	40	45	50

(Based on MRWA, 1990 cited in Austroads 2004)

[1] Any device, which reduces speeds to 20 km/h

The following information complements Austroads (2004) with respect to models and spacings specific to devices that have been shown conclusively to reduce speed.

3.8.2 Models

Several studies have produced models that can be used to estimate the speed changes along a street. Engel & Thomsen (1992) undertook a study of 44 experimental streets that had their layout changed, and speed limit reduced, as a result of a new code introduced in the Danish Road Traffic Act in 1977. The study sought to determine the effects of streets, where the speed limit was reduced to 15 or 30 km/h using a variety of traffic calming devices. The main findings of the model were that:

- The height of a hump has had the most effect on changes in speed. Per 1cm in height, there is an expected speed reduction of 1 km/h, i.e. a 10 cm high hump will reduce speeds by 10 km/h.
- The presence of a narrowing in the carriageway will result in speeds reducing by 4.7 km/h, as will the presence of a double lateral dislocation.
- A single lateral dislocation will result in speeds reducing by only 2km/h.

Given the complexity of the model, the lack of data regarding the devices, and that the model applied to streets with 15 or 30 km/h speed limit, it was considered beyond the scope of this report to investigate the model further.

Barbosa et al. (2000) undertook a case study focusing on traffic calming measures such as raised tables, road humps, road cushions and slow points implemented in sequence. An empirical model was developed, using multiple regression analysis techniques based on data collected at three calibration sites. The speed profile model was shown to be a good representation for the data from the calibration sites, and also provided good representation of the observed profiles at these sites. The exception was the prediction of the effects of slow points on speeds, that produced diverse effects on speeds, which depended on the detailed design. The greatest effect on speeds was produced by raised tables followed by, road humps, slow points and road cushions. While the model is a useful tool, recommendations have been made to further enhance it, plus the model is limited to the use of the above devices. Given that no details of the devices were provided, further investigations into the model were not undertaken.

3.8.3 Sinusoidal Humps

The literature review highlighted a trend towards 75mm high humps, and that the evidence sourced with respect to the device's effectiveness in reducing speed, and resultant effects is limited. Consequently, it is not appropriate to replicate the information provided in several studies (Hass-Klau et al. 1992; TAC 1998; DOT 1998b) for 120, 100 and 80mm high humps respectively.

3.8.4 75/100mm Circular Humps and Raised Tables

Webster & Layfield (1996) found in a study of 88 schemes involving in excess of 500 raised tables and 400 road humps, that the difference in the 'before' mean speeds and hump spacing has more of an effect on 'after' mean speeds, than differences in hump type over the height range 75 – 100mm and is applicable for:

- Circular humps 75 or 100mm high (Watts profile)
- Raised tables, 75mm high with ramp gradients between 1 in 10 and 1 in 15.
- Raised tables, 100mm high with ramp gradients between 1 in 8 and 1 in 10.

The best fitting relationship was established as per (Eq 4) and is illustrated in Table 3.19.

$Vm_{FT/RT} = 3.9 + 0.057S + 0.40Vm_{bef}$ where; (Eq 4)

- $Vm_{FT/RT}$ = mean speed (mph) between flat top or round top (100mm or 75mm)
- S = Hump separation (m)
- Vm_{bef} = Mean speed 'before' (mph)

The number of observations was 73.

- Se (S) = Standard error of the co-efficient, ie 0.006 and S/ Se (S) = 0.057/ 0.006 = 9.5
- Se (Vm_{bef}) = Standard error of the co-efficient Vm_{bef}, ie 0.05 and V/ Se(Vm_{bef}) = 0.4/ .05 = 8.0

As S/ Se (S) and V/ Se(Vm_{bef}) are both > 2, and are both significantly different to zero, the coefficients have been included in (Eq 4).

Table 3.19: Estimated hump[1] spacing required to achieve a target mean 'after' speed between humps (mph)

Mean 'before' speeds (mph)	Hump spacing (m)						
	20	40	60	80	100	120	140
	Mean 'after' speeds (mph)						
20.0	13	14	15	16	18	19	20
25.0	15	16	17	18	20	21	22
30.0	17	18	19	20	22	23	24
35.0	19	20	21	22	24	25	26

(Source: Webster & Layfield 1996)

[1] – For circular humps, 75/100 mm high; raised tables, 75mm high (ramp gradient 1 in 10 to 1 in 15) and raised tables, 100mm high (ramp gradient 1 in 8 to 1 in 10).

The metric version of (Eq 4) is illustrated by (Eq 5) and Table 3.20.

$Vm_{FT/RT} = 6.3 + 0.092S + 0.40Vm_{bef}$ where: (Eq 5)

- $Vm_{FT/RT}$ = mean speed (km/h) between flat top or round top (100mm or 75mm)
- S = Hump separation in metres

Table 3.20: Estimated hump[1] spacing required to achieve a target mean 'after' speed between humps (km/h)

Mean 'before' speeds (km/h)	Hump spacing (m)						
	20	40	60	80	100	120	140
	Mean 'after' speeds (km/h)						
30.0	20	22	24	26	28	29	31
40.0	24	26	28	30	32	33	35
50.0	28	30	32	34	36	37	39
55.0	30	32	34	36	38	39	41

(Based on Webster & Layfield 1996)

[1] – For circular humps, 75/100 mm high; raised tables, 75mm high (ramp gradient 1 in 10 to 1 in 15) and raised tables, 100mm high (ramp gradient 1 in 8 to 1 in 10).

3.8.5 'S' and 'H' Humps

DOT (1998b) details the relationship the 85th percentile 'after' speeds between one set of "S" and one set of "H" Humps spaced about 100m apart.

3.8.6 Road Cushions

Hass-Klau et al. (1992) advised that as far as the desired speed is concerned, distances between the cushions should be the same as for road humps as per Table 3.21, assuming a 31 km/h road hump.

Table 3.21: Distance between road humps (assuming 30 km/h hump)

Desired maximum speed between humps (km/h)	Distance between humps (m)
35.4	50
40.2	100
45.1	150

(Based on C.R.O.W 1988 cited in Hass-Klau et al. 1992)

Layfield & Parry (1998) reported on a study of 34 schemes where road cushions were used, the majority of which were installed on roads with 30 mph (48 km/h) speed limits and on bus routes. They established a relationship for cushions 75mm high, with an on/off gradients of 1 in 8 and a side gradients of 1 in 4 as follows for mean speed. The road cushion spacing and width were statistically significant at the 1% and 5% level respectively.

$$V_{mn\ (bet)} = 26.89 + 0.096s - 0.0071w \quad \text{(Eq 6)}$$

Where $V_{mn\ (bet)}$ = mean speed midway between cushions (mph)
s = longitudinal spacing between cushion layouts (m)
w = cushion width (mm)

The number of observations was 29
The standard error of the coefficients: se (s) = 0.020, se (w) = 0.0026
And s/se(s) = 0.096/0.02 = 4.8 and w/se (w) = 0.0071/0.0026 = 2.7. As both values are > 2, and are significantly different to zero the coefficients have been included in (Eq 6).

The metricated version of (Eq 6) is illustrated for:

- 1600 wide cushions by (Eq 7) and 1900 wide cushions by (Eq 8) and Table 3.22.
  - $V_{mn\ (bet)} = 36.39 + 0.154s - 0.0071w$ (1600mm) (Eq 7)
  - $V_{mn\ (bet)} = 35.00 + 0.155s - 0.0071w$ (1900mm) (Eq 8)

Where $V_{mn\ (bet)}$ = mean speed midway between cushions (km/h)

- s = longitudinal spacing between cushion layouts (m)
- w = cushion width (mm)

Table 3.22: Estimated cushion spacing required to achieve a target mean 'after' speed between cushions

Cushion width (mm)	Cushion spacing (m)						
	20	40	60	80	100	120	140
	Mean 'after' speeds (km/h)						
1600	28	31	34	37	40	44	47
1900	25	28	31	34	37	40	43

(Based on Layfield & Parry 1998)

In addition, Layfield & Parry (1998) established a relationship between spacing and 85th percentile speeds. The road cushion spacing was statistically significant at the 1% level.

$$V_{mn\ (bet)} = 14.81 + 0.152s \quad \text{(Eq 9)}$$

Where $V_{85\ (bet)}$ = 85th percentile speed midway between cushions (mph)
s = longitudinal spacing between cushion layouts (m)

The number of observations was 27

The standard error of the coefficients: se (s) = 0.030 and s/se(s) = 0.152/ 0.030 = 5.1. As the value > 2, and are significantly different to zero the coefficients have been included in (Eq 9).

The metricated version of (Eq 9) is illustrated by (Eq 10) and Table 3.23.

$$V_{mn\ (bet)} = 23.8 + 0.245s \qquad \text{(Eq 10)}$$

Table 3.23: Estimated cushion spacing required to achieve a target 85th percentile 'after' speed between cushions

Cushion spacing (m)						
20	40	60	80	100	120	140
85th percentile 'after' speeds (km/h)						
29	34	39	43	48	53	58

(Based on Layfield & Parry 1998)

3.8.7 Slow Points

Sayer et al. (1998) reported on a study of 12 schemes where data was collected by local authorities at points 'between' slow points. The small data sets, and variability in the speed measurement locations prohibited the development of a reliable speed spacing relationship and concluded that

- The speed between slow points would be influenced by:
  - The speeds of vehicles at the slow points, and
  - the distance between successive measures, and
  - the 'before' speeds.
- It was likely that the vehicle speeds would follow a similar relationship to that for road humps and that further research would be required to verify this.

3.8.8 Summary

The speed/distance relationship data is summarised as follows:

- Maximum speeds between slow points, refer to Table 3.18
- Humps/ raised tables, refer to Table 3.20 for target 'after' mean speeds.
- Road cushions, refer to Table 3.22 for target 'after' mean speeds.
- Road cushions, refer to Table 3.23 for target 'after' 85th percentile speeds.

3.9 Literature Review Summary

3.9.1 Review of objectives

As stated previously the scope was altered to:

1. Define the concepts of speed management, traffic calming and LATM schemes.
2. Define device classification systems.

3. Discuss the general theory as to how devices work.
4. Rank the effectiveness of the device in reducing speeds and the resultant effects based on the available evidence as strong, moderate or limited.

This section covers the above points.

3.9.2 Speed management, traffic calming and LATM

Speed management, traffic calming and LATM, are defined in section 3.1 of this report.

3.9.3 Device Classification Systems

A number of device classification systems exist (Table 3.2) and the Austroads (2004) categories have been adopted for use in this report.

3.9.4 General Theory on how devices work.

While a number of devices reduce speed to varying degrees by moving vehicles vertically or laterally, devices work differently as outlined in section 3.3.1.

3.9.5 Traffic Calming Devices – Crossing speeds

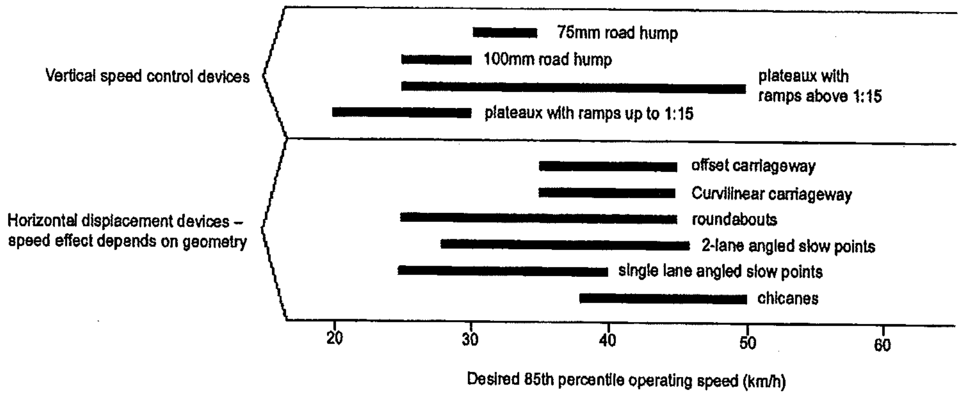
Typical results of different devices effectiveness in reducing speed are illustrated in Table 3.24 and Figure 3.30.

Table 3.24: Expected reduction effect of various traffic calming measures

	Upper limit of maximum sp (km/h)		Upper limit of 85th percentile speed (km/h)		Range of mean speed (km/h)	
	'Before'	'After'	'Before'	'After'	'Before'	'After'
Vertical Shifts in the carriageway	100	40	75	30	45 - 65	18 - 25
Lateral shifts in the carriageway	100	65	75	45	45 - 65	22 -35
Road narrowing to a single lane	100	65	75	45	45 - 65	22 -35
Roundabout	100	65	75	45	45 - 65	22 -35
Road narrowing to a redu width	100	95	75	70	45 - 65	40 -55
Central islands	100	95	75	70	45 - 65	40 -55

(Source: Harvey 1992)

Figure 3.30: Reported operating speeds for selected device types



(Source: Brindle 1999 cited in Austroads 2004)

3.9.6 Traffic Calming Devices - Recommended Devices

Table 3.25 lists in descending priority order based on the literature review, and mean crossing speeds those devices where strong evidence was sourced supporting the assertion the devices effectively reduce speed, and where they have not been superseded by other devices, and can be constructed easily.

Table 3.25: Crossing Speed Summary - Conclusive (Literature Review)

Device	Height (mm)	'Before'	'After'	Reduction	Notes
		Mean (85th percentile) (km/h)	Mean (85th percentile) (km/h)	Mean (85th percentile) (km/h)	
Raised Tables (UK)	70-80	Not assessed	20.6 (23.8)	- (-)	Ramp gradient varies between 1 in 13 and 1 in 15.
Circular road humps	75	Not assessed	23.7 (30.6)	- (-)	-
Raised tables (UK)	100	Not assessed	25.7 (33.5)	- (-)	Ramp gradient varies between 1 in 15 and 1 in 20.
Road cushions	75	48.3 (57.3)	27.8 (34.9)	20.5 (22.4)	-
Slow point (single lane)	-	55.2 (63.1)	34.0 (41.8)	21.2 (21.3)	-
Slow Point (two lane)	-	61.0 (67.4)	42.6 (50.4)	18.4 (17.0)	-
Perimeter threshold	-	-	See note	-	Typical reduction 3.2 km/h

These results are consistent with the results illustrated in Table 3.24 and Figure 3.30.

Table 3.26 expands on Table 3.25, and details the installation criteria, and likely effects for each device.

Table 3.26: Recommended traffic calming devices - Installation and effect summary

Device and Installation Criteria	Effects	Details	Notes
Raised table Install 75mm high raised tables on routes used by buses or emergency vehicles when the installation of road cushions is not practical. Install either 75 or 100mm high raised tables on routes where pedestrian crossing points are warranted, eg courtesy crossing[1], pedestrian crosswalk[2] or wombat crossing.	• Traffic volumes may change by +18% and – 54% and on average reduce by 24%. • Reported injury accidents may reduce by up to 65%. • Noise may decrease by up to 4dB(A).	Comfort	• The minimum recommended ramp grading to prevent grounding is 1 in 8, however a 1 in 15 gradient should be used in conjunction with a 75mm high platform, such that the peak vertical acceleration remains slightly below 0.7g for cars and minibuses crossing the ramp at 32 and 24 km/h respectively, and slightly above 0.7g for buses crossng the ramp at 24 km/h.
		Installation[1]	• DOT (1996) provides guidance on ramp gradients where raised tables are installed on inclines ('downhill' ramps vary between 1 in 10 and 1 in 13; 'uphill' ramps vary between 1 in 10 and 1 in 35), but provides no details relating the gradient of the road to the uphill'/ 'downhill' ramp gradients, and peak vertical accelerations. • Raised tables have been installed on roads with speed limits of 32 or 48 km/h and gradients of between 5 and 10%. • Ramps gradients not less than 1 in 15 are regarded as cycle friendly.
		Plateau length	• The length should exceed the wheel base of the design vehicle in order to obtain the pitching motion. • The difference in crossing speeds between different plateua is insignificant, i.e. mean speeds over 6.0 – 6.5m long plateaus are about 1.6 km/h faster than plateaus in the range 2.0 - 2.5m.
		Crossing speeds	• No relationship exists between traffic speed and ramp gradients over the range 1 in 10 to 1 in 15, but higher speeds are found at sites with ramp gradients of 1 in 20 or shallower, e.g: - Mean crossing and 85th percentile speeds are 20.6 and 23.8 km/h for raised tables, 70 – 80mm high with ramp gradients varying between 1 in 10 and 1 in 15. - Mean crossing and 85th percentile speeds are 26.0 and 33.5 km/h for raised tables, 100mm high with ramp gradients varying between 1 in 15 and 1 in 20.
		Speed/ spacing relationship	• The spacing and 'before' speeds are the key variables influencing the 'after' mean speeds. • Models relating mean speed and spacing, have not been developed for 100mm raised tables with ramp gradients between 1 in 15 and 1 in 20. • Models relating 85th percentile speeds and spacing have not been developed for raised tables

To be read in conjunction with Austroads (2004)

[1] – Differs slightly from Austroads (2004)

[2] – American practice differs from the advice offered in Austroads (2004)

Table 3.26 cont: Recommended traffic calming devices - Installation and effect summary

Device and Installation Criteria	Effects	Details	Notes
75mm high circular humps Install on routes not used by buses or emergency vehicles on a regular basis.	• Traffic volumes may reduce by between 2 and to 43%, on average a 24% reduction. • Reported injury accidents may reduce by up to 65%. • Noise may decrease by up to 4dB(A).	Comfort	• Peak vertical acceleration is below 0.7g for cars crossing the hump at 30 km/h.
		Installation	• Circular profile, 3.7m long. • Circular humps have been installed on a road with a 48 km/h speed limit and a gradient between 5 and 10%. • Circular humps are generally installed on roads with a speed limit ≤ 50 km/h. • Attitudinal surveys indicate that the majority of the community appear to support hump schemes.
		Crossing Speeds	• Allows mean and 85th percentile crossing speeds of 23.7 and 30.6 km/h respectively, and provides a good compromise regarding speed reduction and peak vertical acceleration.
		Speed/ spacing relationship	• The spacing and 'before' mean speeds are the key variables influencing the 'after' mean speeds. • Models relating 85th percentile speeds and spacing have not been developed for circular humps

To be read in conjunction with Austroads (2004)

Table 3.26 cont: Recommended traffic calming devices - Installation and effect summary

Device and Installation Criteria	Effects	Details	Notes
Road cushions Install on routes used regularly by buses and emergency vehicles in order to minimise comfort and delay, or as an alternative to circular humps on residential streets.	• Traffic volumes may reduce by between 2 and to 48%, on average a 24% reduction. • Noise may reduce.	Installation	• The maximum height should not exceed 75mm, and be no less than 2m in length in order to avoid longitudinal grounding. Where single cushion schemes are installed, the maxium height should not exceed 65mm. • The maximum width should not exceed 2000mm, 1600 - 1700 is recommended on bus routes in order to allow buses to straddle the cushion. • Where cushions are unaffected by parking, surveys have shown that up to 55% of cars and 90% of buses straddle the cushions centrally or approximately centrally. • Hass Klau et al. (1992) recommends restricting parking up to 10m in front of the cushions, in order to allow buses to 'straight line' the cushions. • Attitudinal surveys indicate a low level of support following the installation of schemes, with residents indicating that the cushions are not as effective as humps in slowing traffic • Single cushion should be installed in combination with kerb extensions. • Paired cushions should be installed on higher volume two way roads, and can be combined with kerb extensions and/or islands. Without islands, up to 20% of motorists drive between cushions. • Three abreast should be installed on high volume, wide two way roads without kerb extensions. Up to 40% of motorists drive between the nearside and middle cushions. • Cushions can easily be relocated on site for minimal expense. • Cushions may be inappropriate where vehicles have dual rear wheels.
		Comfort	• Peak vertical accelerations are below 0.7g at crossing speeds below 32 km/h, and regarded as being cycle friendly. • Attitudinal surveys indicate the public are more supportive of road humps than road cushions.
		Crossing Speeds	• Mean and 85th percentile crossing speed of 27.8 and 34.9 km/h respectively and and
		Speed/ spacing relationship	• The spacing and width are the key variables influencing 'after' mean speeds. • The spacing is the key variable influencing 'after' 85th percentile speeds.

To be read in conjunction with Austroads (2004)

Table 3.26 cont: Recommended traffic calming devices - Installation and effect summary

Device and Installation Criteria	Effects	Details	Notes
Slow points[1] Install on routes that cater for buses and emergency vehicles as an alternative to road humps and raised tables to minimise discomfort. Claims of vehicle damage and increased maintenance and repair costs sustained have been made by fleet operators.	• Traffic volumes may reduce by up to 15% at single lane slow points, and up to 7% at two way slow points. • The overall reported accident frequency reduces by up to 54%, but the risk may increase for cyclists if the layout allows motorists to overtake them through the slow point.	Installation	• May be installed on gradients up to 8%. • Path angles of 10^0 should result in 85^{th} percentile speeds in excess of 48.3 km/h. • Attitudinal surveys suggest that the community dislike horizontal deflections more than they dislike road humps. • Cycle bypasses are recommended at sites with high traffic volumes.
		Crossing Speeds	• Path angles greater than 15^0 should reduce mean speeds to less than 32.2 km/h. • Path angles of 15^0 - 20^0 should result in 85^{th} percentile speeds of 32.2 – 40.2 km/h.
		Speed/ spacing relationship	• Models relating mean and 85^{th} percentile speeds to speed/spacing have not been developed for Slow Points.
Pereimter threshold treatment	As per Austroads (2004)		• Reduce speeds up to 3.2 km/h.

To be read in conjunction with Austroads (2004), [1] – Austroads (2004), ie slow points may restrict emergency vehicles and buses.

3.10 Recommended Research

Further investigations could be carried out to investigate:

- Some unresolved issues pertaining to those devices that are effective in reducing speed.
- Those devices that could potentially be applied in New Zealand, but where it has not be possible to find strong evidence supporting the assertion they are effective devices in reducing speeds.
- Community attitudes to the various devices, as this is a key parameter to installing a scheme.

3.10.1 Unresolved Issues

Raised Table (70 – 80mm)

Gradients

Raised tables can be installed on gradients of up to 8% (TAC 1998) and 10% (Webster & Layfield 1996). However, no mention was made in the literature review of peak vertical accelerations being measured on gradients, although Webster & Layfield (1996) provided advice on the gradients of 'uphill' and 'downhill' ramps. What is currently unclear is the relationship between peak vertical acceleration and road gradient.

75mm Circular humps

Comfort

Various studies have established that the peak vertical acceleration of cars crossing a circular ramp is below 0.7g at speeds below 30 km/h, and that humps may be constructed on gradients up to 8%. However, no mention was made in the literature review of peak vertical accelerations being measured on gradients.

Cyclists

Webster & Layfield (1996) advised that their study of 75mm high circular humps and raised tables did not appear to cause cyclists any problems, but this has not been discussed in detail.

Raised Table (100mm)

Comfort

Braaksma and Weber (2000) highlighted in a study, that the peak vertical acceleration across a 100mm high hump with a Seminole profile varied between 0.62g and 0.7g, based on a car crossing the hump at 40 km/h. Other studies focusing specifically on 100mm high raised tables could not be sourced.

Speed/Spacing Relationship

Models produced to date, do not cover 100mm high raised tables with ramp gradients between 1 in 15 and 1 in 20.

Road Cushions

Comfort

Various studies have established that the peak vertical acceleration of vehicles crossing a ramp is below 0.7g at speeds between 24 and 40 km/h. No information has been sourced relating peak vertical acceleration to gradient, a likely scenario given cushions are being promoted as an alternative to circular humps, and raised tables, both of which can be used on gradients of up to 8%.

Delay

No information could be sourced on the comparative delay imposed by road cushions, versus those imposed by road humps and speed tables.

Length

The 2m minimum length specified in DOT (1998a) is used as the basis for road cushions installed in New Zealand and differs from the minimum length (3m) specified in Austroads (2004). It is unclear whether to what extent the difference lengths influences various factors, such as comfort, grounding or longitudinal straddling.

Slow Points

Cycle Bypasses

Cycling bypasses are recommended at sites with high traffic volumes, but limited information exists with respect to what is defined as a high traffic volume.

Speed/Spacing relationship

Statistically reliable models have not been produced to date.

Perimeter Threshold Treatments

Wheeler et al. (1993) cited in DOT (1993b) suggests that speeds are not sustained over any distance and the expected speed reduction is unlikely to exceed 3.2 km/h, and that perimeter threshold treatments should supplement other traffic calming devices.

3.10.2 Devices

Table 3.27 lists devices being used in New Zealand, that warrant further investigation, such that they can be installed with practitioners being aware of the likely effects.

Table 3.27: Device summary - Recommended for further investigation

Device	Reason for inclusion
Centre blister	To enable it to be applied with a degree of certainty.
Kerb extension	Used widely in New Zealand.
Parking	Assessing the safety implications of angle parking that has been installed without any associated traffic calming devices.
Mid-block median	Used widely in New Zealand often with kerb extensions
Reduce lane width	To assess the associated safety implications.
Carriageway narrowing	Used in New Zealand, but it may not be as cost effective as other measures.

3.10.3 Community Attitudes

The literature review has highlighted that the community in the UK favours vertical, over horizontal devices and is sceptical about the effectiveness of road humps in reducing speeds. While community acceptance is a key element to installing a scheme, limited research appears to have been undertaken in New Zealand on what devices the community is willing to accept. The devices listed in Tables 3.26 and 3.27 could form the basis of a research project.

[blank]

4. NZ CASE STUDIES

One of the listed objectives, is to compare devices in New Zealand and their effectiveness in reducing speed with . The scope was subsequently altered to allow the results of the case studies to be compared with the findings/conclusions resulting from the literature review. For each case study this will be achieved by commenting on the:

- Installation, and highlighting apparent differences from the findings of the literature review.
- Effects, and highlighting apparent differences from the findings of the literature review.

The comments are based on the available information included within this report, and include suggestions for further research specific to each case study. For comparison purposes, the case studies are listed in Table 4.1, together with the RCAs that participated in the RSS21 Survey (LTSA, 2004).

Table 4.1: RCA Case Study Summary

No	Device	No. of RCA's using traffic calming devices on 'local' roads[1]	Case Study Response	Notes
		RCA	RCA	
1	Road bump	-	-	
2	Road humps	22	3	
3	Raised table	10	3	
4	Road cushion	4	5	
5	Road depression	-	-	
6	Raised intersection platform	12	-	
7	Centre blister	-	1	
8	Impellor	-	-	
9	Lane narrowing	50	4	RSS 21: Includes kerb line alterations, road markings and islands/ pedestrian refuges
10	Driveway link	-	-	
11	Slow point	9	2	
12	Roundabout	13	1	RSS21 does not distinguish between mini-roundabouts and roundabouts
13	Mini-roundabout	-	-	
14	Signs	28	-	RSS 21: Includes traffic signs and changed priority at intersections
15	Pedestrian Crossing	-	-	
16	Perimeter threshold treatments	14	2	
17	Shared zone	-	-	
18	Tactile surface treatment	19	-	RSS 21: Includes surface treatments and rumble strips
19	Modified tee intersection	-		
	Totals	-	21	

[1] – LTSA, 2004

In addition the LTSA (2004) reported that five RCA's used measures not listed in the above table, i.e.:

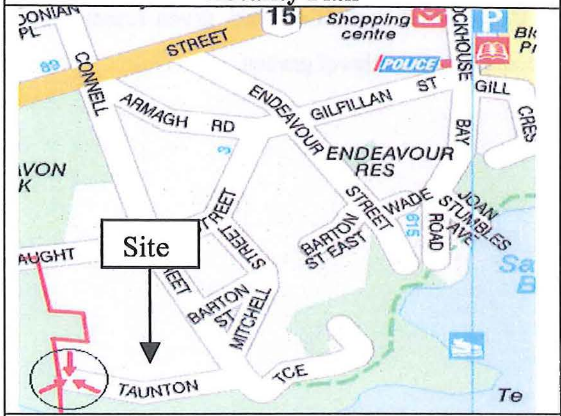
- Road depressions.
- Raised medians.
- Four-way stops.
- One way slow points.

Each case study is discussed in turn, noting that vehicles have been classified as per the Austroads classification, LCV (types 1 and 2) and HCV(types 3 to 13). Some examples involved roads that are not classified as 'local', but were included to illustrate the effectiveness of the device in reducing speed.

Watts profile road humps - Taunton Terrace, Auckland

Details of the scheme are outlined in the following table and Appendix H.

Table 4.2: Scheme Overview – Taunton Terrace

Locality Plan	'After' installation
	

Background		
The scheme involved the installation of 2 Watts profile road humps at the request of local residents, with funding provided by the community board, as the justification for the scheme did not meet the requirements of Auckland City Councils LATM guidelines. Watts profile road humps were selected on the basis of being the least cost option.	**Roadside development**	Residential/Reserve
	Road hierarchy	Local
	Speed limit	50 km/h
	Carriageway width	4.5m
	Kerb side parking	No
	Gradient	Unavailable
	Bus route	No
	Date devices installed	8/ 2004
	Device spacing	85m

Post Installation Impact Summary

ADT (7 day)	'Before' not assessed vs 'After' 77 vpd (7 – 8/ 2005)

Speeds[1]	'Before' not assessed			'After' (7 –8/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)		-		31.6	31.6	30.0
• 85th %ile (km/h)				38.9	38.9	29.5
• Sample size				729	724	5
• SD (km/h)				7.9	7.9	7.8

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Auckland City Council except the plan, http://www.wises.co.nz/)

1 – Measured opposite No. 17 approximately midway between the two humps.

Installation

Watts profile (100mm high circular) humps have been installed contrary to the literature recommendations, that the maximum height should be restricted to 75mm in order to minimise the likelihood of grounding, and to minimise peak vertical accelerations particularly for heavy vehicles.

Potential effects

- The mean 'after' speed of 31.6 km/h:
    - Appears to lie within the expected range listed in Table 3.20.

- Is less than the maximum theoretical speed of 42km/h, based on a 22 km/h device crossing speed and a maximum speed differential of 20 km/h.

Suggested further research

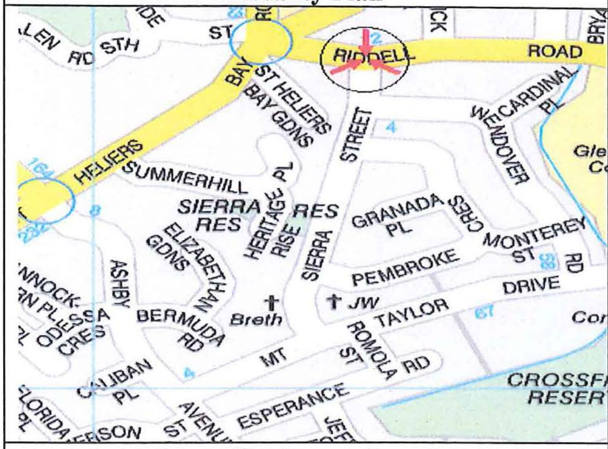
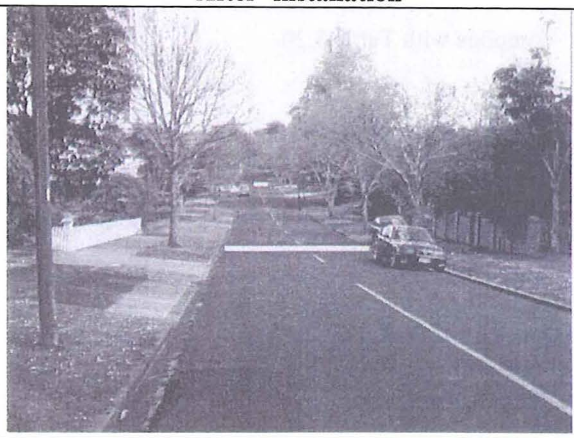
Further research could include:

- Measuring the peak vertical acceleration for the hump on the steepest section of road, given research to date, appears to have concentrated on measuring peak vertical accelerations on level grades.
- Checking for evidence of grounding.

Watts profile road humps – Sierra Street, Auckland

Details of the scheme are outlined in the following table and Appendix H.

Table 4.3: Scheme Overview – Sierra Street

Locality Plan	**'After' installation**
	

Background

The scheme involved the installation of 5 Watts profile road humps following an initial request by residents in 1989 for the street (635m long) to be traffic calmed. The humps were installed outside numbers 5/6, 12/15, 24/29, 55/50 and between the churches near the Taylor Drive intersection and were selected on the basis of being the least cost option.

Roadside development	Residential
Road hierarchy	Local
Speed limit	50 km/h
Carriageway width	8m
Kerb side parking	Some restrictions apply
Gradient	Generally level
Bus route	No
Date devices installed	8/2003
Device spacing	Varies between 80m and 160m

Post installation impact summary

ADT (7 day)	'Before' not assessed, 'After' 929vpd (4/2005)

Speeds[1]	'Before' not assessed			'After' (4/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	-			41.1	-	-
• 85^{th} %ile (km/h)				49.4	-	-
• Sample size				6504	-	-
• SD (km/h)				9.0	-	-

Other comments

- Speed surveys were supplied by Auckland City Council in hardcopy format.
- 93% of residents were in favour of road humps being installed in a survey undertaken in 2001.

(Table based on information supplied by Auckland City Council except the plan, http://www.wises.co.nz/)

[1] - Measured opposite No. 46

Installation

Watts profile (100mm high circular) humps have been installed contrary to the literature recommendations, that the maximum height should be restricted to 75mm in order to minimise the likelihood of grounding, and to minimise peak vertical accelerations particularly for heavy vehicles.

Potential Effects

- The mean 'after' speed of 41.1 km/h midway between the devices is less than the maximum theoretical speed of 42km/h, based on a 22 km/h device crossing speed, and a maximum speed differential of 20 km/h.

Suggested further research

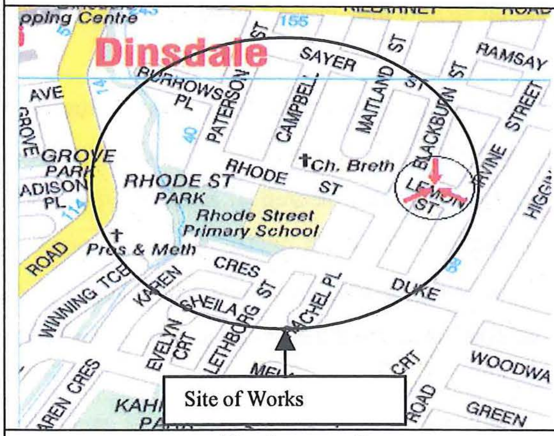
Further research could include:

- Undertaking a post installation ‘attitudinal survey”, and comparing the results with the 2001 survey.
- Measuring the distances between the humps, in order to confirm whether the speed/distance relationship complies with Table 3.20.

Watts profile road humps – Blackburn LATM, Hamilton

Details of the scheme are outlined in the following table and Appendix H.

Table 4.4: Scheme Overview – Blackburn LATM

Locality Plan	'After' installation looking south from #36 Blackburn
	

Background	Roadside development	Residential
The scheme involved the installation of 14 Watts profile road humps and seven Perimeter threshold treatments using splitter islands. The scheme was installed as it met Hamilton City Council's traffic calming warrant criteria (high 85th percentile speed plus through traffic and crashes). Watts profile humps were selected because none of the roads are used as bus routes.	**Road hierarchy**	Local
	Speed limit	50 km/h
	Carriageway width	8 – 12m
	Kerb side parking	Yes
	Gradient	Level
	Bus route	No
	Date devices installed	4 – 5/2005
	Device spacing	Varies between 166m and 260m

Post installation impact summary

ADT (7 day)	'Before' 575vpd (3/2005), 'After' 485 vpd (9/2005), Irvine St 'Before' 499vpd (3/2005), 'After' 241 vpd (10/2005), Campbell St

Speeds[1]	'Before' (3/2005)			'After' (9/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
Mean (km/h)	47.0	47.0	46.0	37.4	37.5	32.1
85th %ile (km/h)	56.9	56.9	55.4	45.4	45.4	40.3
Sample size	4053	3959	94	4374	4277	97
SD (km/h)	11.3	11.4	8.6	8.6	8.6	7.6
Speeds[2]	'Before' (3/2005)			'After' (9/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	44.4	44.1	41.6	40.8	39.4	49.4
• 85th %ile (km/h)	54.4	54.4	48.2	51.8	49.7	62.3
• Sample size	3539	3509	30	1498	1285	213
• SD (km/h)	11.8	11.8	8.8	11.8	10.8	13.3

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Hamilton City Council except the plan, http://www.wises.co.nz/)

1 – Measured near No. 24 Irvine Street (53m from nearest hump, spaced 205m apart)

2 – Measured near No. 56 Campbell Street (86m from nearest hump, spaced 215m apart)

Installation

Watts profile (100mm high circular) humps have been installed contrary to the literature recommendations, that the maximum height should be restricted to 75mm in order to minimise the likelihood of grounding, and to minimise peak vertical accelerations particularly for heavy vehicles. While Hamilton City Council was willing to accept the height being constructed to between 75 and 110mm, three humps had to be reconstructed, as the specified height was exceeded by up to 30mm.

Potential effects

- Volumes have decreased by an average of 32.4%, within the range specified in the literature review of between –2 and 43%.
- The 'before' and 'after' surveys were undertaken in the same location, but not midway between the devices. Calculation of the mean speeds midway between the humps in Irvine and Campbell streets using (Eq 5) results in speeds of 44.0 and 43.8 km/h respectively. Assuming that the maximum theoretical speed midway between the devices on Irvine and Campbell Streets is 42 km/h, based on a 22 km/h device crossing speed and a maximum speed differential recommended of 20 km/h, it is possible that the actual mean speed midway between the devices will exceed this value. This can only be confirmed by undertaking another survey midway between the devices.
- The mean speeds between the devices (not midway) have reduced by on average 6.6 km/h (-14.4%), with the reductions *significant* at the 0.05 test level (See Table G7).
- The 85th percentile speeds between the devices (not midway) have reduced by on average 7.0 km/h (-12.6%).
- The speeds of HCV's in Campbell Street have increased 'after' installation. This could be a function of the small 'before' dataset, the humps not being constructed to the correct profile, or systematic bias error. Hamilton City Council was unable to explain why this was occurring.

Suggested further research

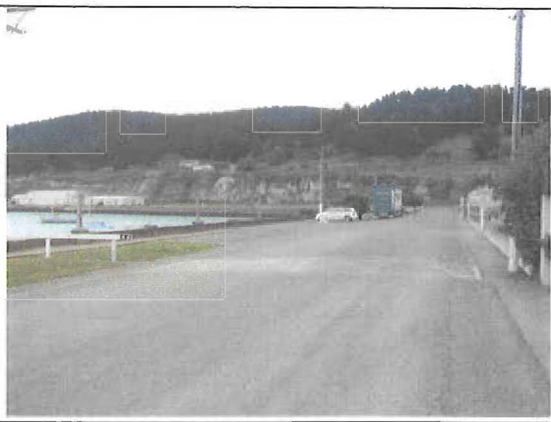
Further research could include checking:

- For evidence of grounding.
- The speeds midway between the devices, in order to confirm whether the model (Eq 5) is valid for distances in excess of 140m.

Watts profile road humps – Waterfront Road , Oamaru

Details of the scheme are outlined in the following table.

Table 4.5: Scheme Overview – Waterfront Road

<table>
<tr><th>'After' installation looking west</th><th colspan="2">'After' installation looking east</th></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td rowspan="9">Background
The scheme involved the installation of 2 Watts profile road humps on a "No Exit" road to slow traffic and promote the road as a 'shared zone' given the number of pedestrian movements across the road associated with rowers carrying rowing shells to/from the storage sheds to the beach for launching.</td><td>Roadside development</td><td>Reserve/ Commercial</td></tr>
<tr><td>Road hierarchy</td><td>Local</td></tr>
<tr><td>Speed limit</td><td>50 km/h</td></tr>
<tr><td>Carriageway width</td><td>9.2m</td></tr>
<tr><td>Kerb side parking</td><td>On berm</td></tr>
<tr><td>Gradient</td><td>Level</td></tr>
<tr><td>Bus route</td><td>No</td></tr>
<tr><td>Date devices installed</td><td>3/2004</td></tr>
<tr><td>Device spacing</td><td>130m</td></tr>
</table>

<table>
<tr><th colspan="7">Post installation impact summary</th></tr>
<tr><td>ADT (7 day)</td><td colspan="6">All – 'Before' not assessed, 'After' 535 vpd (5/2005)</td></tr>
<tr><td rowspan="2">Speeds[1]</td><td colspan="3">'Before' not assessed</td><td colspan="3">'After' (5/2005)</td></tr>
<tr><td>All</td><td>LCV's</td><td>HCV's</td><td>All</td><td>LCV's</td><td>HCV's</td></tr>
<tr><td>• Mean (km/h)</td><td colspan="3" rowspan="4">-</td><td>33.7</td><td>33.9</td><td>28.4</td></tr>
<tr><td>• 85th %ile (km/h)</td><td>43.2</td><td>43.6</td><td>35.6</td></tr>
<tr><td>• Sample size</td><td>4668</td><td>4461</td><td>212</td></tr>
<tr><td>• SD (km/h)</td><td>9.6</td><td>9.6</td><td>7.0</td></tr>
<tr><th colspan="7">Other comments</th></tr>
<tr><td colspan="7">- Speed surveys undertaken using the Metrocount ® vehicle classification system.</td></tr>
</table>

(Table based on information supplied by Waitaki District Council)

[1] – Measured at RAMM station 805 approximately midway between the humps.

Installation

Watts profile (100mm high circular) humps have been installed contrary to the literature recommendations, that the maximum height should be restricted to 75mm in order to minimise the likelihood of grounding, and to minimise peak vertical accelerations, particularly for heavy vehicles. The humps were selected on the basis as being the most suitable profile for heavy vehicles and trailers. Despite the apparent conflict with the literature review, no difficulties have been reported.

Potential effects

- The mean 'after' speed of 33.7 km/h midway between the devices:
  - Appears to lie within the expected range listed in Table 3.20.
  - Is less than the maximum theoretical speed of 42km/h, based on a 22 km/h device crossing speed and a maximum speed differential of 20 km/h.
- 21 of the 24 heavy vehicles using Waterfront Road daily, are two, three or four axle trucks or buses, reflecting the commercial land use.

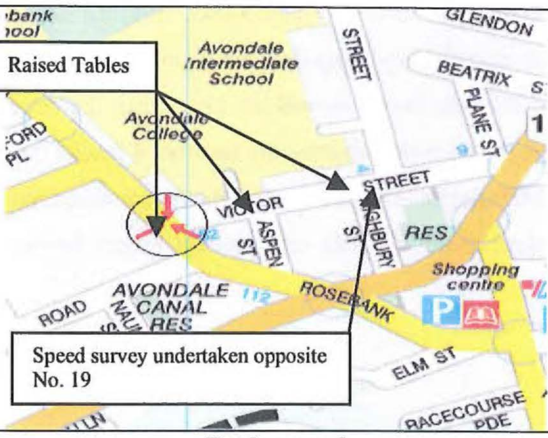
Suggested further research

Further research could include checking for evidence of grounding.

Raised table - Victor Street, Auckland

Details of the scheme are outlined in the following table and Appendix H.

Table 4.6: Scheme Overview – Victor Street

Locality Plan	'After' installation looking west from east of Holly Street
	

Background

This scheme has evolved in two stages:

- Stage 1 involved the construction of islands east of Highbury St.
- Stage 2 involved the construction of 2 x 100mm high raised tables with 1.5m long ramps sloping at 1 in 15, with 4m and 6m long plateaus. An additional raised table, 100mm high, with 1.5m long ramps sloping at 1 in 15, and a 4m long plateau was constructed at the site of the existing islands. Stage 2 was undertaken as part of a walking and cycling project with the objective of slowing traffic. Signs have been erected advising trucks to use an alternative route due to the narrowness of the route in the vicinity of the traffic calming devices.

Roadside development	Educational/ Residential
Road hierarchy	Local
Speed limit	50 km/h
Carriageway width	9m
Kerb side parking	Partial restrictions
Gradient	Level
Bus route	No
Date devices installed	Stage 1, prior to 1989 Stage 2, 2004/2005
Device spacing	125 - 200m

Post installation impact summary

ADT[1] (7 day) 'Before' not assessed, 'After' 2851 (6/2002)

Speeds[2]	'Before' (11/2003), Eastbound			'Before' (11/2003), Westbound		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	49.1	-		44.4	-	
• 85th %ile (km/h)	57.6			54.0		
• Sample size	51			55		
• SD (km/h)	8.1			7.6		

Other comments

- Speed surveys undertaken using hand held radar gun

(Table based on information supplied by Auckland City Council except the plan, http://www.wises.co.nz/)

1 – Between Rosebank and Aspen

2 – Opposite No. 19, between Highbury and Holly

Installation

Installing raised tables 100mm high is contrary to the literature review recommendations, that the maximum height should be restricted to 75mm, in order to minimise the likelihood of grounding.

Potential effects

The only effect assessed, is the crossing speed in close proximity to No. 19 Victor Street. Both the mean (44.4 – 49.1 km/h) and 85th percentile (54.0 – 57.6 km/h) speeds are significantly more than the typical crossing mean, and 85th percentile speeds of 26.0 and 33.5 km/h respectively. The westbound speeds are lower than the eastbound, a reflection possibly of motorists braking prior to reaching the raised table, whereas the eastbound results may reflect acceleration. The results need are inconclusive given the small sample sets, and the fact they were measured prior to the raised table, and not as vehicles crossed it. Further more, speed/ distance relationships cannot be determined from the available information.

Suggested further research

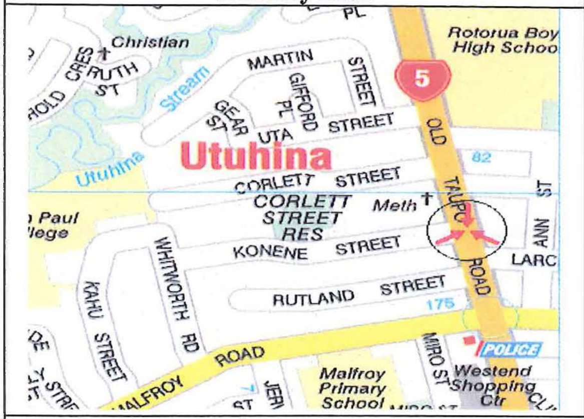
Further research could include:

- Measuring the 85th percentile speeds midway between the devices during periods when traffic flows are not disrupted by school-related activities, and as part of a wider study to establish a speed/ distance relationship.
- Checking for evidence of grounding.

Raised table – Konene Street, Rotorua

Details of the scheme are outlined in the following table and Appendix H.

Table 4.7: Scheme Overview – Konene Street

Locality Plan	'After' installation looking southwest from #25
	

Background		
The scheme involved the installation of 5 raised tables, 100mm high with a 6m long plateau and 1m long ramps at 1 in 10.	**Roadside development**	Residential
	Road hierarchy	Local
	Speed limit	50 km/h
	Carriageway width	8m
	Kerb side parking	No restrictions apply
	Gradient	Approximately 1%
	Bus route	Yes[2]
	Date devices installed	5/2004
	Device spacing	120 to 150m.

Post installation impact summary					
ADT (7 day)	Not assessed				
Speeds[1]	'Before' not assessed			'After' (7/2005)	
	All	LCV's	HCV's	(Westbound)	(Eastbound)
• Mean (km/h)	-			36.6	34.5
• 85th %ile (km/h)				42.0	40.0
• Sample size				84	179
• SD (km/h)				5.7	6.1
Other comments					
- Speed surveys undertaken using hand held radar gun.					

(Table based on information supplied by Rotorua District Council except the plan, http://www.wises.co.nz/)

[1] – Measured midway between the raised tables installed opposite no's 27 and 37, 120m apart.
[2] – School buses only

Installation

- The installation of a 100 mm high raised table with 1 in 10 ramps, is contrary to the findings of the literature review, which recommends that on bus routes, raised tables 75mm high with 1 in 15 ramps are a good compromise between reducing speeds, minimising discomfort and reducing the likelihood of grounding.
- Rotorua District Council were unable to confirm whether road cushions (the preferred treatment on bus routes as per the literature review) were considered as an option for this site.

Potential effects

- The mean 'after' speed midway between the devices varies between 34.5 and 36.6 km/h, and appears to lie within the expected range listed in Table 3.20.
- Crash rate. Three speed related crashes had occurred in the period five years prior to installation, and one in the period 18 months after installation. The time period is too short to determine whether the reduction in crash rate is statistically significant.

Suggested further research

Further research could include:

- Measuring the peak vertical acceleration across the devices, to confirm that the peak vertical accelerations exceed 0.7g. To allow comparison with the peak vertical accelerations across 75mm high raised tables, similar vehicles and crossing speeds should be used.

Raised table - Tuckers Road, Christchurch

Details of the scheme are outlined in the following table and Appendix H.

Table 4.8: Scheme Overview – Tuckers Road

Locality Plan	**'After' installation**
	

Background		
The scheme involved the installation of 7 x 100mm high raised tables with sloping ramps of 1 in 20 and a realigned intersection. Five of the tables have 6m long plateaus, one with a 4m long plateau and one with an 8m long plateau. The variation in plateau width and selection of raised tables was partly governed by the objective of facilitating the introduction of aesthetics.	**Roadside development**	Residential
	Road hierarchy	Local
	Speed limit	50 km/h
	Carriageway width	12.8 – 13.2m
	Kerb side parking	Unrestricted
	Gradient	Level
	Bus route	No
	Date devices installed	11 – 12/2004
	Device spacing	80 – 130m

Post installation impact summary

ADT (7 day)	'Before' 2085 vpd (6/2000), 'After' 2121 vpd (6/2005)					
Speeds[1]	'Before' (6/ 2000)			'After' (6/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	51.4	51.5	48.5	42.6	42.7	33.3
• 85^{th} %ile (km/h)	59.4	59.4	55.1	49.3	49.3	40.3
• Sample size	16885	16370	515	22688	22478	210
• SD (km/h)	9.2	9.2	8.2	7.6	7.6	7.7

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Christchurch City Council except the plan, http://www.wises.co.nz/)

[1] – Measured opposite No's 35/37 between two raised tables (35m from the nearest raised table spaced 130m part).

<u>Installation</u>

The installation of 100 mm high raised tables is contrary to the findings of the literature review, which recommends limiting the height to a maximum of 75mm, in order to reduce the likelihood of grounding. The 1 in 20 ramps have subsequently been replaced with steeper ramps, the slopes of which cannot be verified at present. A 75mm high raised table with 1 in 15 sloping ramps, would have provided a good compromise between speed/comfort/grounding and is likely to have resulted in mean and 85^{th} percentile crossing speeds, of 20.6 and 23.8 km/h respectively.

<u>Potential effects</u>

- Volumes are virtually unchanged which is contrary to the literature review, which suggests variations of between +18 and –54%, and on average a reduction of –24%.
- The mean speed of 42.6 km/h is higher than the expected range listed in Table 3.20, noting that Table 3.20 does not apply to 100mm high raised tables with 1 in 20 ramps, and the speeds were not measured midway between the devices.
- The mean speeds between the devices (not midway) have reduced by 8.8 km/h (-17.1%), %), with the reductions *significant* at the 0.05 test level (See Table G7).
- The 85th percentile speeds between the devices (not midway) have reduced by 10.1km/h (-17.0%).
- It is likely that the maximum theoretical speed midway between the devices of 46km/h based on a 26 km/h device crossing speed, and a maximum speed differential of 20 km/h may be exceeded, a situation that could be confirmed by undertaking a survey midway between the devices.

<u>Suggested further research</u>

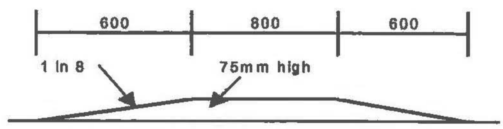
It is unclear why a significant reduction in volumes has not been achieved. Further information needs to be obtained regarding the spacing of all raised tables, heights and ramps slopes , plus the timing of surveys relative to changes in the reconstruction of the devices in order for statistically reliable conclusions to be made.

Road cushions (Asphaltic Concrete) - Rimu Street, Hamilton

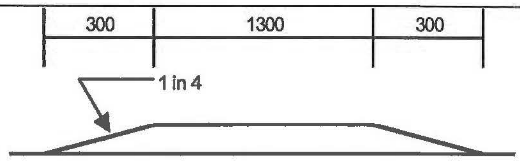
Details of the scheme are outlined in the following table and Appendix H.

Table 4.9: Scheme Overview – Rimu Street

Cushion, parallel to travel direction



Cushion, perpendicular to travel direction



'After' installation

Background

This scheme involved the installation of 5 sets of 1.9m wide asphaltic concrete road cushions x 75 mm high (four sets, three abreast and 1 set, paired). The cushions were installed as a trial.

Roadside development	Residential
Road hierarchy	Local
Speed limit	50 km/h
Carriageway width	11m
Kerb side parking	Yes/No
Gradient	Varies 1 – 2%
Bus route	Part of the route
Date devices installed	12/2004 – 1/2005
Device spacing	160 – 275m

Post installation impact summary

ADT (7 day)	'Before' 2766 vpd (7/2002), 'After' 1851 vpd (4/2005), Maeroa to Forest Lake

Speeds[1]	'Before' not assessed			'After' (4/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)		-		47.0	47.0	47.5
• 85th %ile (km/h)				53.6	53.6	54.7
• Sample size				13255	12471	2318
• SD (km/h)				7.7	7.7	8.0

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Hamilton City Council)

[1] – Measured midway between sites 4 and 5, 175m apart.

<u>Installation</u>

The installation of a 1.9m wide road cushions is contrary to the findings of the literature review, which recommends 1.6m wide road cushions (including ramps) be installed on bus routes. Hamilton City Council advises that buses travel over the southern portion of Rimu Street (Maeroa to Roach Street), and were driven over the 1.6m and 1.9m wide cushions, before the decision was made to adopt the 1.9m wide cushion. The reason for adopting the 1.9m wide cushions, was that the 1.6m wide cushions were perceived as being too narrow.

Potential effects

- Volumes have decreased by 33%, within the range specified in the literature review of between –2 and 48%.
- The mean 'after' speed of 47.0 km/h is slightly less than the mean 'after' speed of 48.6 km/h calculated using Eq. 8, and is less than the maximum theoretical speed midway between the devices of 47.8 km/h, based on a 27.8 km/h crossing speed and a maximum speed differential of 20 km/h.
- The 85th percentile 'after' speed of 53.6 km/h, is less than the 85th percentile 'after' speed of 66.7 km/h calculated using Eq. 10.

Suggested further research

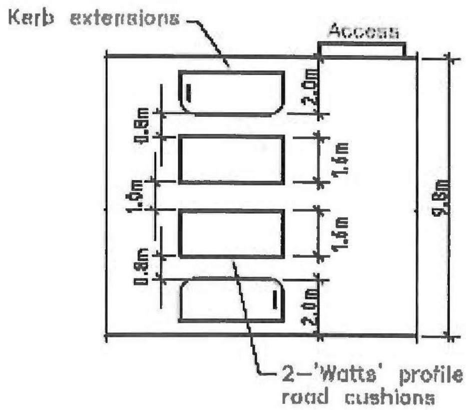
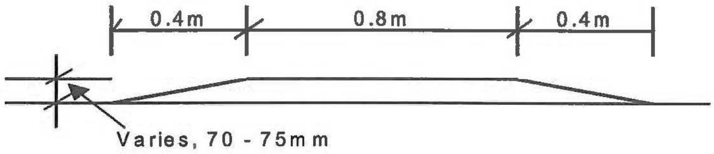
Future research could include:

- Undertaking some surveys midway between the devices, in order to check the model is valid for distances in excess of 140m.
- Validating the compliance rates with which motorists straddle or drive between the paired cushions, given they are located near a bend, and non-compliance will increase the risk of motorists having a "head-on".

Road cushions (Asphaltic Concrete) - Ranui Avenue, Timaru

Details of the scheme are outlined in the following table and Appendix H.

Table 4.10: Scheme Overview – Ranui Ave

'After' installation looking west	**Cushion, plan**
	
Cushion, perpendicular to travel direction	
	

Background		
The scheme involved installing 1.6m wide road cushions in a paired layout at two locations, plus intersection islands to slow traffic and allow the passage of buses without unduly compromising passenger comfort. Justification for the scheme included a fatality, an unacceptable volume of traffic on a 'local' road and 85th percentile 'before' speed of 58.7 km/h. Cushions were selected as an alternative to Watts Profile humps given Ranui Street is a bus route, and a 'softer' treatment was desired by the community.	**Roadside development**	Commercial/residential
	Road hierarchy	Local
	Speed limit	50 km/h
	Carriageway width	9.8m
	Kerb side parking	Yes
	Gradient	Level
	Bus route	Yes
	Date devices installed	10/2004
	Device spacing	111m

Post installation impact summary						
ADT (7 day)	'Before' 3445 vpd (9/2000), 'After' 2161 vpd (11/2004)					
Speeds[1]	'Before' (9/2000)			'After' (11/2004)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	51.1	51.1	47.7	38.3	38.3	37.7
• 85th %ile (km/h)	58.7	58.7	55.4	44.6	44.6	46.8
• Sample size	24135	23793	342	15629	15417	212
• SD (km/h)	8.3	8.3	8.6	6.8	6.8	8.3
Other comments						
- Speed surveys undertaken using the Metrocount ® vehicle classification system.						

(Table based on information supplied by Timaru District Council)

[1] – Measured at RAMM station 290 midway between the cushions.

Installation

- This paired road cushion scheme has been constructed without an island between the cushions, which the literature review has highlighted, may result in a degree of non-compliance by motorists who elect to drive between the cushions as opposed to straddling the cushions. The layout ensures that, no matter what line is taken, at least one wheel is on the cushion. Timaru District Council advise that they are considering installing a yellow centreline on both approaches to each set of cushions.

Potential effects

- Following installation, initial complaints were received on how to ride over them and what line to take. This has sorted itself out, and the scheme has appeared to have been accepted by the community, and is considered as a successful treatment in achieving the desired objective of reducing speed.
- Volumes have decreased by 37%, within the range specified in the literature review of between –2 and 48%.
- The mean 'after' speed of 38.3 km/h is slightly less than the mean 'after' speed of 42.1 km/h calculated using Eq. 7, and is less than the maximum theoretical speed midway between the devices of 47.8 km/h, based on a 27.8 km/h crossing speed and a maximum speed differential of 20 km/h.
- The 85th percentile 'after' speed of 44.6 km/h is less than the 85th percentile 'after' speed of 51.0 km/h calculated using Eq. 10.
- The mean speeds midway between the devices have reduced by 12.8 km/h (-25.0%), and 85th percentile speeds by 14.1km/h (-24.0%), with the reductions in mean speed *significant* at the 0.05 test level (See Table G7).

Suggested further research

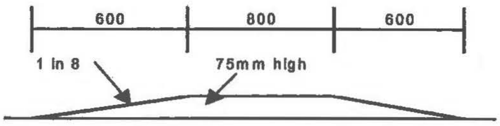
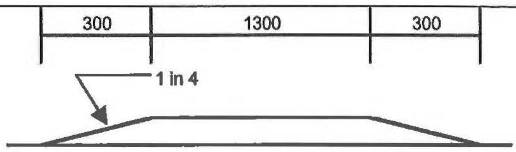
Future research could include:

- Validating the compliance rates with which motorists straddle or drive between the cushions, and establishing a relationship between conflicts and traffic volumes.
- Checking for evidence of grounding.

Road cushions (Rubber) - Waimarie Street, Hamilton

Details of the scheme are outlined in the following table and Appendix H.

Table 4.11: Scheme Overview – Waimarie Street

Cushion, parallel to travel direction	**'After' installation**
	
Cushion, perpendicular to travel direction	
	

Background	**Roadside development**	Residential/ undeveloped
The scheme involved installing 1.9m wide road cushions in a paired layout at seven locations in Nawton with two of the locations being in Waimarie Street.	**Road hierarchy**	Local
	Speed limit	50 km/h
	Carriageway width	11m
	Kerb side parking	Yes
	Gradient	Undulating, 5% max.
	Bus route	School bus route
	Date devices installed	9/2003
	Device spacing	210m

Post installation impact summary

ADT (7 day)	'Before' 2658 vpd (5/2002), 'After' 1572 vpd (2/2004) in Livingstone Ave					
Speeds[1]	'Before' not assessed			'After' (11/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	-			37.5	37.6	37.1
• 85th %ile (km/h)				45.7	45.7	49.3
• Sample size				8639	8181	458
• SD (km/h)				9.1	8.9	11.0

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Hamilton City Council)

1 – Measured opposite No. 32 Waimarie Street, approximately midway between the cushions.

Installation

- This paired road cushion scheme has been constructed without an island between the cushions, which the literature review has highlighted, may result in a degree of non-compliance by motorists, who elect to drive between the cushions as opposed to straddling the cushions.
- The 1.9m wide cushions are contrary to the findings of the literature review, which recommends 1.6m wide cushions on bus routes, in order to minimise discomfort.

Potential effects

- Volumes have decreased by 40.9%, within the range specified in the literature review of between –2 and 48%.
- The mean 'after' speed of 37.5 km/h is slightly less than the mean 'after' speed of 54.1 km/h calculated using Eq. 8, and is less than the maximum theoretical speed midway between the devices of 47.8 km/h, based on a 27.8 km/h crossing speed and a maximum speed differential of 20 km/h.
- The 85th percentile 'after' speed of 45.7 km/h is less than the 85th percentile 'after' speed of 75.3 km/h calculated using Eq. 10.

Suggested further research

Further research could include:

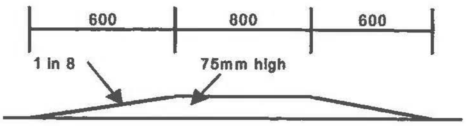
- Undertaking more surveys midway between the devices, in order to check the model is valid for distances in excess of 140m.
- Validating the compliance rates with which motorists straddle or drive between the cushions, and establishing a relationship between conflicts and traffic volumes.

Road cushions (Rubber) - Magnetic/Harrington Streets, Dunedin

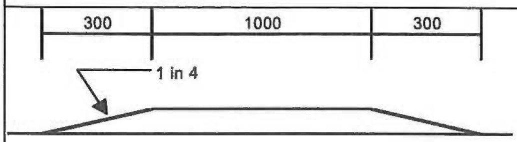
Details of the scheme are outlined in the following table and Appendix H.

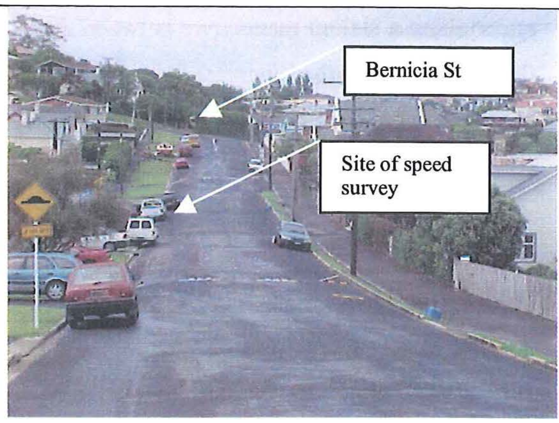
Table 4.12: Scheme Overview - Magnetic/Harrington Streets

Cushion, parallel to travel direction	'After' installation looking north (Magnetic)



Cushion, perpendicular to travel direction





Background		
The scheme involved the installation of 1.6m wide road cushions in a paired layout at five locations, with the objective of reducing the number of motorists travelling well in excess of the speed limit, and to alleviate community concerns. Rubber road cushions were selected because buses use the route, they are not as abrupt as Watts profile humps, and could be easily relocated at minimal expense.	**Roadside development**	Residential
	Road hierarchy	Local
	Speed limit	50 km/h
	Carriageway width	Varies, 10 – 11m
	Kerb side parking	Yes
	Gradient	Undulating, 10% max.
	Bus route	Yes
	Date devices installed	4/2005
	Device spacing	Varies, 96 – 144m

Post installation impact summary						
ADT (7 Day)	'Before' 520 vpd (3/2005), 'After' 414 vpd (8/2005)					
Speeds[1]	'Before' (3/2005)			'After' (8/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	47.3	47.5	45.4	39.1	39.4	36.7
• 85^{th} %ile (km/h)	57.2	57.6	53.6	48.6	49.0	45.7
• Sample size	4083	3784	299	3260	2922	338
• SD (km/h)	11.1	11.3	8.8	9.8	9.9	8.5
Other comments						
- Speed surveys undertaken using the Metrocount ® vehicle classification system.						

(Table based on information supplied by Dunedin City Council)

[1] – Measured at RAMM Station 172 (Magnetic St) midway between the cushions, 96m apart.

Installation

- The scheme has been installed without parking restrictions near the cushions contrary to the findings of the literature review, thereby preventing buses from taking a straight line, and straddling the cushions.
- One set of cushions was offset longitudinally from the another in order to avoid driveways, resulting in drivers undertaking a slalom manoeuvre between them, in order to avoid straddling them. The public highlighted that the risk of a crash had increased due to motorists behaviour, and the proximity of the site an intersection. A cushion was subsequently removed, and reinstated as a paired layout adjacent to a driveway, without any complaint from the residents, contrary to the findings of the literature review.

Potential effects

- Vehicles have been observed driving between the cushions, and buses are unable to straddle the cushions during periods when vehicles are parked adjacent them. Community attitudes highlight that this is unacceptable, although it is highly likely that motorists were driving down the centre of the road prior to the installation of the road cushions.
- Volumes have decreased by 20.4%, within the range (-2 and 48%) specified in the literature review., and is the cause of public concern, as some of the traffic has diverted down streets where the visibility at intersections with adjoining through roads is severely restricted.
- The mean 'after' speed of 39.1 km/h is slightly less than the mean 'after' speed of 39.8 km/h calculated using Eq. 7, and is less than the maximum theoretical speed midway between the devices of 47.8 km/h, based on a 27.8 km/h crossing speed and a maximum speed differential of 20 km/h.
- The 85th percentile 'after' speed of 48.6 km/h is slightly more than the 85th percentile 'after' speed of 47.3 km/h calculated using Eq. 10.
- The mean speeds midway between the devices have reduced by 8.2 km/h (-17.3%),%), with the reductions *significant* at the 0.05 test level (See Table G7).
- The 85th percentile speeds midway between the devices have reduced by 8.6 km/h (-15.0%).
- The site has been included in CAS as a "Site of Interest", but it is too early to determine whether any significant changes to the crash rates in the area have occurred.

Suggested further research

Further research could include:

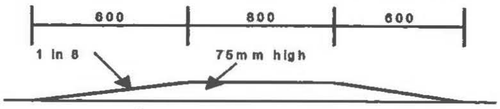
- Measuring the peak vertical acceleration across the cushions as part of a wider study, and compare the results with those that have been installed on a grade, e.g. Maitland Street, Dunedin.
- Validating the compliance rates with which motorists straddle or drive between the cushions, and establishing a relationship between conflicts and traffic volumes.

Road cushions (Rubber) – Maitland Street, Dunedin

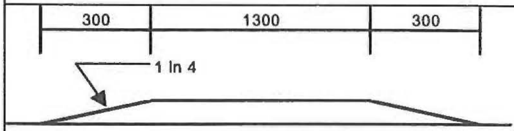
Details of the scheme are outlined in the following table and Appendix H.

Table 4.13: Scheme Overview – Maitland Street

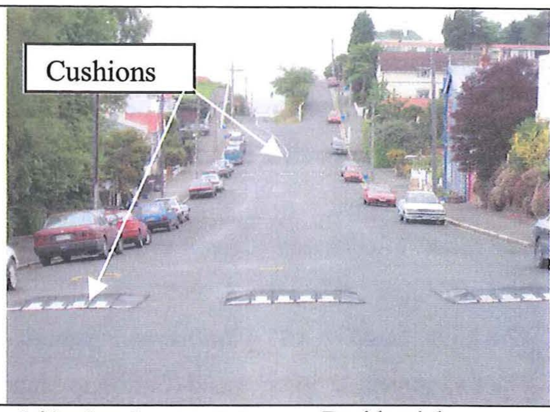
Cushion, parallel to travel direction



Cushion, perpendicular to travel direction



'After' installation looking south



Background

The scheme involved the installation of 1.9m wide road cushions, three abreast at five locations to reduce the percentage of motorists travelling well in excess of the speed limit. Rubber road cushions were selected because the cushions are not as abrupt as Watts profile humps, and can be relocated at minimal expense.

Roadside development	Residential
Road hierarchy	Local
Speed limit	50 km/h
Carriageway width	14m
Kerb side parking	Yes
Gradient	Varies, 8% max.
Bus route	No
Date devices installed	12/ 2004
Device spacing	Varies 86 – 91m (4 sets), 1 set standalone

Post installation impact summary

ADT (7 Day): 'Before' 1565 vpd (9/2001), After' 1624 vpd (2/2005), Carroll to Manor
'Before' 1645 vpd (10/2003), 'After' 1471 vpd (2/2005), Princes to Jones

Speeds[1]	'Before' (9/2001)			'After' (2/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	50.1	-		35.7	35.8	27.5
• 85th %ile (km/h)	59.0			42.8	42.8	33.5
• Sample size	11019			13506	13353	153
• SD (km/h)	13.2			7.5	7.5	6.2
Speeds[2]	**'Before' (10/2003)**			**'After' (2/2005)**		
	All	LCV's	HCV's	All	LCV's	HCV's
Mean (km/h)	45.0	45.1	34.0	37.3	37.4	30.3
85th %ile (km/h)	51.8	51.8	44.6	45.4	45.4	38.9
Sample size	11520	11419	101	10644	10555	89
SD (km/h)	7.6	7.5	10.1	8.1	8.1	9.4

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Dunedin City Council)

[1] – Measured at RAMM Station 543 approximately midway between the cushions, 86m apart, Carroll to Manor.

[2] – Measured at RAMM Station 128, 41m north of the southernmost cushion, Princes to Jones.

Installation

- The scheme was undertaken as a 'trial' as the devices had never been used in Dunedin. The installation was delayed until summer, to ensure that road users were accustomed to using the cushions prior to winter, when the street can be subjected to ice.

Potential effects

- Community feedback suggests that pedestrian safety has been increased due to lower speeds.
- The differences in traffic volumes are inconclusive, and more surveys are programmed for 2006 to confirm the extent of the change.
- The mean 'after' speed (Carroll to Manor) of 35.7 km/h is slightly more than the mean 'after' speed of 34.8 km/h calculated using Eq. 8, and is less than the maximum theoretical speed midway between the devices of 47.8 km/h, based on a 27.8 km/h crossing speed and a maximum speed differential of 20 km/h.
- The 85^{th} percentile 'after' speed (Carroll to Manor) of 42.80 km/h, is slightly less than the 85^{th} percentile 'after' speed of 44.9 km/h calculated using Eq. 10.
- The mean speeds at RAMM stn 543 have reduced by 14.4 km/h (-28.7%)%), with the reductions *significant* at the 0.05 test level (See Table G7).
- The 85^{th} percentile speeds at RAMM stn 543 have reduce by 16.2 km/h (-27.5%).
- The site has been included in CAS as a "Site of Interest", but it is too early to determine whether any significant changes to the crash rates in the area have occurred.

Suggested further research

Further research could include:

- Validating the compliance rates with which motorists' straddle or drive between the cushions.
- Measuring the peak vertical acceleration across the cushion given one set has been installed on a grade, and comfort is a critical impact that needs to be considered when selecting devices.

Centre Blister - Sunset Road, Rotorua

Details of the scheme are outlined in the following table and Appendix H.

Table 4.14: Scheme Overview – Sunset Road

'After' installation of slow point	'After' installation of Centre blister
	

Background		
The scheme involved the installation of 2 x Watts profile (100mm high circular) road humps, 1 x centre blister, and one two-way angled slow point. The scheme was set out on site in consultation with local residents and the maintenance contractor.	**Roadside development**	Residential
	Road hierarchy	Arterial
	Speed limit	50 km/h
	Carriageway width	11m
	Kerb side parking	Yes
	Gradient	Approximately 1.8%
	Bus route	Yes
	Date devices installed	11/2004
	Device spacing	140m (Slow Point to Centre Blister).

Post installation impact summary				
ADT (7 Day)	Not assessed			
Speeds	All[1], 'Before' (7/2004)		All[2], 'After' (6/2005)	
	Eastbound	Westbound	Eastbound	Westbound
• Mean (km/h)	54.3	55.9	41.0	41.9
• 85th percentile (km/h)	60.0	63.0	49.3	50.0
• Sample size	90	100	119	74
• SD (km/h)	5.9	3.5	7.6	8.9
Other comments				
- Speed surveys undertaken using hand held radar gun				

(Table based on information supplied by Rotorua District Council)

[1] – Measured opposite No. 387 approximately midway between the two devices, 140m apart.

[2] – Measured through the Centre blister.

Installation

- Installation of a centre blister appears to be contrary to the advice contained in the literature review for Level 1 Traffic Calming that involves, "actions to restrain traffic speed and lessen traffic impacts at the local level, where traffic volumes, levels of service and capacity are not an issue".
- No construction or "As Built" drawings exist.

Potential effects

- The mean 'after' speed of approximately 41 km/h through the centre blister, is approximately 13 km/h higher than the highest recorded of any of the devices studied, i.e. road cushions.
- The 85th percentile 'after' speeds through the centre blister is similar to the results (49.3 km/h) through SCM's (Forbes and Gill 1999). A direct comparison is not possible, given the lack of data available for both sites.

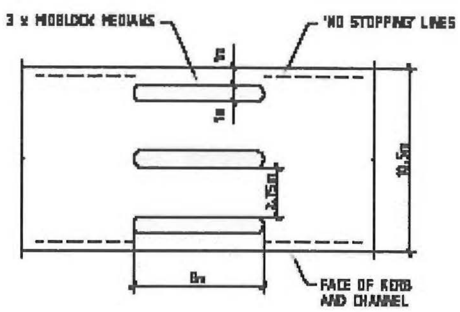
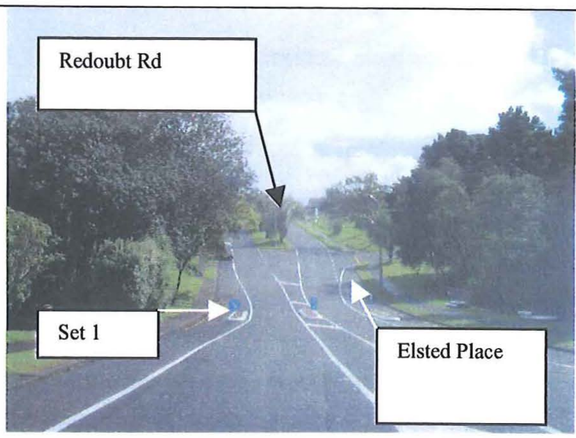
Suggested further research

- Further research could include:
  - Measuring the 'after' speeds midway between the devices as part of a wider study to establish a speed/ distance relationship.
  - Establishing a relationship as part of a wider study, between the geometry of the centre blister and crossing speeds.

Midblock median - Goodwood Drive, Manukau City

Details of the scheme are outlined in the following table and Appendix H.

Table 4.15: Scheme Overview – Goodwood Drive

Midblock Median, plan	**'After' installation looking west, towards set 1**
	

Background		
This scheme involved installing six sets of islands three abreast, varying in length between 3 and 8m, thereby narrowing the carriageway. The scheme was justified on the basis of unacceptable 85th percentile speeds . The islands were selected as the preferred device, as devices such as road humps were deemed unacceptable on a bus route, with the width between the island varying between 2.75 and 2.80m.	**Roadside development**	Residential
	Road hierarchy	Collector
	Speed limit	50 km/h
	Carriageway width	10.5 – 11.5m
	Kerb side parking	Yes
	Gradient	Undulating, see plan
	Bus route	Yes
	Date devices installed	9/2005
	Device spacing	64 – 107m

Post installation impact summary

ADT[1] (7 Day) 'Before' 4854 vpd (5/2005), 'After' 5257 vpd (12/2005)

Speeds[2]	Outside No. 8 and 19		Outside No. 16 and 29a		Outside No. 35	
	'Before' All	'After' All	'Before' All	'After' All	'Before' All	'After' All
• Mean (km/h)	54.8	52.8	50.6	47.2	53.4	50.3
• 85th percentile (km/h)	61.9	59.4	56.5	53.3	60.1	56.9
• Sample size	36465	38196	34940	36207	34646	35996
• SD (km/h)	7.9	7.7	6.7	6.7	7.7	7.5

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Opus International Consultants, Paeroa)

[1] – Mean of three surveys

[2] - Refer to the appendix G for further details

Installation

- The treatment is an approach that has not been highlighted previously with respect to "Lane Narrowings".

- As a result of feedback from residents during the final phase of consultation, the locations of the islands differs slightly from the details shown on the drawings.
- The extent of "No Stopping" restrictions on some approaches may require a cyclist to deviate abruptly from their line of travel, should they wish to travel to the left of the innermost island.

Potential effects

- The volumes have increased by approximately 8.3%, which is contrary to the findings of the literature review, i.e. no effect. The 2.75 – 2.8m width between the islands caters for less than 1.5% of the total traffic volume, whereas the remaining 98.5% of motor vehicles are likely to have a wheel base of approximately 1.75m.
- The mean speeds between the devices (not midway) have reduced by on average 2.8 km/h (-5.3%),with the reductions *significant* at the 0.05 test level (See Table G7).
- The 85^{th} percentile speeds between the devices (not midway) have reduced by on average 3.3 km/h (-5.5%).
- A speed/ distance relationship has been calculated using a best fit, but should be used with caution, given it is based on only four devices and a device spacing of between 67 and 107m, i.e.
  - Mean speed midway between devices (km/h) = 38.9 km/h + 0.13 x spacing (m). (Eq. 11)
  - 85^{th} percentile speed midway between devices = 44.2 km/h + 0.142 x spacing (m). (Eq. 12)
- Crashes will be monitored, but not necessarily by CAS.

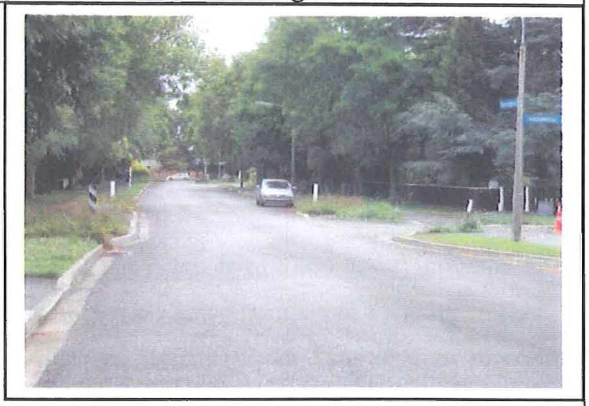
Suggested further research

- Further research could include:
  - Monitoring the compliance rate with which cyclists used the section of road provided for them, i.e. between the kerb and channel and the outermost islands.
  - Measuring the speed through the device, as an aid to preparing speed profiles in accordance with the procedure outlined in Austroads (2004).
  - Measuring the speeds of vehicles using different spacings, and utilising islands that have been temporarily installed.

Carriageway narrowing - Thorrington Road, Christchurch

Details of the scheme are outlined in the following table and Appendix H.

Table 4.16: Scheme Overview – Thorrington Road

'After' installation of Driveway link at south end of street	'After' installation of Narrowing opposite Woodbridge Street
	

Background

The scheme involved narrowing a 440m long road x 11m wide as part of a programmed kerb and channel renewal project, with the objective of slowing traffic, and reducing the volume of traffic using Thorrington Road as a short cut.

Roadside development	Residential
Road hierarchy	Local
Speed limit	50 km/h
Carriageway width	8m 'after' narrowing
Kerb side parking	Yes
Gradient	Level
Bus route	No
Date devices installed	11/2003 – 7/2004
Device spacing	Not applicable

Post installation impact summary

ADT (7 Day): 'Before' 968 vpd (2/2003), 'After' 336 vpd (2/2005)

Speeds[1]	'Before' (2/2003)			'After' (2/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	44.7	44.8	41.5	39.6	39.7	33.9
• 85th percentile (km/h)	53.6	53.6	54.4	48.6	48.6	42.8
• Sample size	7806	7737	69	3089	3038	51
• SD (km/h)	10.0	10.0	14.7	9.5	9.2	20.1

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Christchurch City Council)

[1] – Measured opposite No. 32.

Installation

- In addition to narrowing the carriageway, other features included are a single lane slow point, intersection narrowings (6m between kerbs) and a half road closure (exit only) as illustrated in Appendix H, such that a motorist will encounter a device approximately every 200m.

Potential effects

- The effects assessed (Smith 2005) are volumes, speeds and crashes.
  - Volumes having decreased by approximately 65%, contrary to the advice sourced in the literature review (i.e. no effect). The result may be due to the altered layout requiring drivers to take a longer route as opposed to the carriageway narrowing.
  - Mean speeds have decreased by approximately 5 km/h and that "...in general, residents opinion of the speed of traffic in the area is that it has reduced...", and "...a small number of drivers were still travelling at excessive speeds".
  - No crashes have been reported since the scheme was implemented.

  In addition, Smith (2005) recommended that a further formal review be undertaken in three years time with basic continuous monitoring being carried out annually.
- Speeds have reduced, as summarised in Table 4.16a. The results show that speeds of eastbound traffic have virtually remained unchanged, and speeds of westbound traffic have reduced significantly. For eastbound traffic the carriageway has reduced in width from 11m to 8m and for westbound traffic, from 11m to 6m as they enter an intersection narrowing.

Table 4.16a: Thorrington Road – 'Before' and 'After' speeds

Impact	Eastbound		Westbound	
	'Before' (2/2003)	'After' (2/2005)	'Before' (2/2003)	'After' (2/2005)
ADT (7 Day)	639	224	329	112
Mean (km/h)	43.4	40.6	47.3	37.5
85th %ile (km/h)	51.1	49.0	58.3	47.2
Sample size	5170	2088	2636	1001
SD (km/h)	8.7	8.8	11.8	10.7

The results appear to support the findings of the literature review that reducing width has a minimal effect on reducing speeds, i.e.

- The mean speeds on the section reduced from 11 to 8m, reduced by 2.8 km/h (-6.5%), with the reductions *significant* at the 0.05 test level (See Table G7).
- The 85th percentile speeds on the section reduced from 11 to 8m, reduced by 2.1km/h (-4.1%).
- The mean speeds on the section reduced from 11 to 6m, reduced by 9.8 km/h (-20.7%), with the reductions *significant* at the 0.05 test level (See Table G7).
- The 85th percentile speeds on the section reduced from 11 to 6m, reduced by 11.1 km/h (-19.0%).

Suggested further research

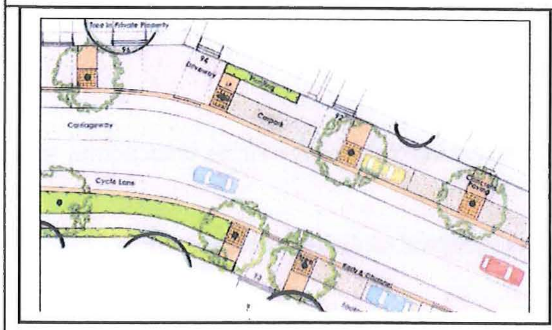
- Further research could include:
  - Monitoring the effect on the crash rate via CAS with respect to carriageway widths, given narrower roads normally have a higher crash rate.

Carriageway narrowing - Creyke Road, Christchurch

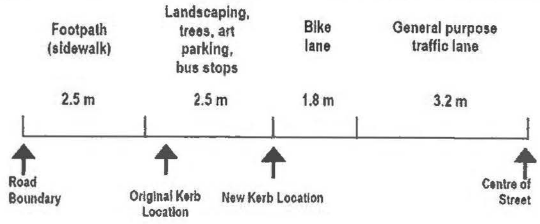
Details of the scheme are outlined in the following table and Appendix H.

Table 4.17: Scheme Overview – Creyke Road

Proposed plan

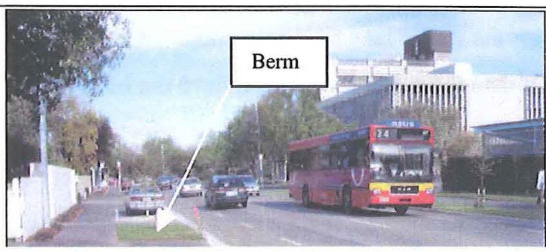


Proposed cross section



'Before' Installation

'After' Installation



Background

The scheme was undertaken as pilot project, and involved 'traffic calming' a 1km long minor arterial road used by 900 cyclists and 13,000 motorists per day. In addition and estimated 1,500 pedestrians who crossed the road daily. The scheme involved reducing the carriageway width, by reconstructing the kerb, installing cycle lanes/pedestrian refuges/threshold treatments at either end of the project, and planting trees in the berm and on the refuge islands.

Roadside development	Residential/ Educational
Road hierarchy	Arterial
Speed limit	50 km/h
Carriageway width	14m 'before', 10m 'after'
Kerb side parking	Yes (indented)
Gradient	Level
Bus route	Yes
Date devices installed	12/2003 - 9/2004
Device spacing	Not applicable

Post installation impact summary

ADT [1] (7 Day) 'Before' 13,746 vpd (3-4/2003), 'After' 11,877 vpd (6/2005)

Speeds	Opposite No. 24		Opposite No. 48/50		Opposite No. 88	
	'Before' All	'After' All	'Before' All	'After' All	'Before' All	'After' All
• Mean (km/h)	47.6	49.7	48.7	49.7	48.4	48.6
• 85th percentile (km/h)	54.0	55.1	54.7	55.4	54.0	54.0
• Sample size	114584	98026	106451	101909	103016	94755
• SD (km/h)	7.6	6.8	7.2	7.2	6.7	6.7

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Macbeth, 2005)

[1] – Average of surveys measured opposite No. 24 and 88, Creyke Road (Refer to Appendix G for further details).

Installation

- The objective was to introduce a "Living Streets" philosophy to Creyke Road as part of a scheduled kerb and channel renewal where the "Living Streets" programme attempts to achieve a better balance amongst road users and between road users and the neighbouring environment.

Potential effects

- The effects have been assessed by Macbeth (2005) who suggested several reasons for no reduction in speed to date, specifically:
  - Better definition of parking, improved road surface and the removal of dish channel and kerbs.
  - Trees are still small and more of them are required.
  - Solid line required for cycle lane marking.
  - Increasing the width of the cycle lane from 1.65m to 1.8m as originally designed, and reducing the width of the traffic lane by a corresponding amount.

  To date the recommendations have not been implemented.
- Traffic volumes appear to have reduced by approximately 13%, however, the March 2003 surveys were influenced by construction work on a parallel route (Fendalton Road) that resulted in traffic being diverted to Creyke Road. The change in volumes is not attributable to this project, whereas the literature review found no effect on volumes as a result of carriageway narrowing.
- The mean speeds increased by on average 1.3 km/h (+2.7%), with the increases *significant* at the 0.05 test level (See Table G7).
- The 85^{th} percentile speeds increased by on average 0.7 km/h (+1.3%), noting that the findings in the literature review conclusively state that reducing width does not automatically result in a reduction in speed.
- Macbeth (2005). The consultant for this project has mentioned that more trees larger than those installed to date may assist in reducing speeds. Research (Kobayashi & Yamanaka 1970; Van der Horst & Riemersma 1984: Blaauw & Van der Horst 1982 cited in Martens et al. 1997) has shown that road users consider speeds exceeding 2 rad/s in the visual periphery (at about 30 degrees to the left and right of the fovea) to be very disturbing. This concept is illustrated in Transit New Zealand's "State highway geometric design manual".

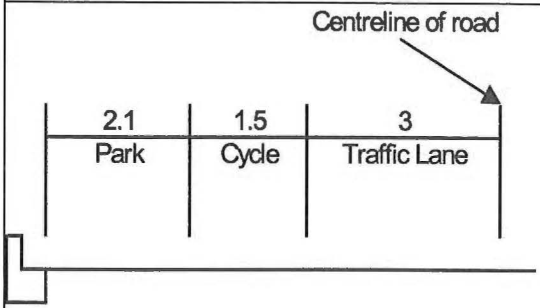
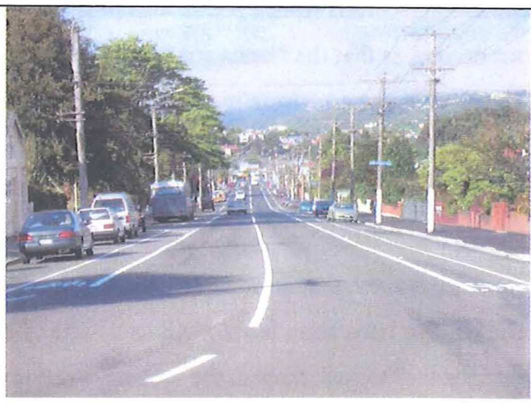
Suggested further research

- Further research could include:
  - The site being monitored to ascertain what the long term impact is on traffic volumes, speeds and crashes, thereby in assisting in determining the degree to which each impact is affected.
  - Increasing the density of information in the visual periphery (i.e. trees on the berm), which may result in road users choosing their speeds, and position on the road in such a way that the angular speed of visual objects in the visual periphery does not exceed the value of 2 rad/ s.

Reduced lane width: North Road, Dunedin

Details of the scheme are outlined in the following table.

Table 4.18: Scheme Overview – North Road

Proposed Cross Section	**'After' installation looking south**
	

Background		
The scheme involved replacing the centreline marking with 2 x 3m wide traffic lanes, and 2 x 1.5m wide cycle lanes along 2 km of road. The objective of the scheme was to allocate road space to cyclists, as a result of North Road being designated a cycle route in January 2003.	**Roadside development**	Commercial/residential
	Road hierarchy	District
	Speed limit	50 km/h
	Carriageway width	13m approx.
	Kerb side parking	Yes
	Gradient	1% approx.
	Bus route	Yes
	Date devices installed	Early 2005
	Device spacing	n/a

Post installation impact summary

ADT (7 Day): 'Before' 11843 vpd (7/2004), 'After' 11743 vpd (8/2005) Chacombe to Glendining; 'Before' 7572 vpd (7/2004), 'After' 6906 vpd (7/2005) James to Calder:

Speed[1]	'Before' (7/2004)			'After' (8/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	47.7	47.7	45.7	47.8	47.9	45.7
• 85th percentile (km/h)	52.6	52.9	51.1	52.9	52.9	51.5
• Sample size	20451	19941	510	81987	80131	1856
• SD (km/h)	5.9	5.9	6.5	6.2	6.1	7.7
Speed[2]	**'Before' (7/2004)**			**'After' (7/2005)**		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	48.4	48.5	46.8	49.2	49.3	46.8
• 85th percentile (km/h)	54.0	54.0	52.9	54.7	54.7	52.9
• Sample size	15991	15224	767	58646	57122	1524
• SD (km/h)	7.2	7.1	7.6	6.4	6.4	7.4

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Dunedin City Council)

[1] – Measured at RAMM station 324 excluding the period immediately before/after school due to the presence of a school pedestrian crossing in close proximity to the survey site, i.e. 8-9am and 3-4pm.

[2] – Measured at RAMM station 1161.

Installation

- The installation did not result in the loss of any parking.

Potential effects

- Feedback received from cyclists was positive regarding the reallocation of road space, whereas feedback from bus drivers, is that the "lanes are too narrow".
- Traffic volumes are virtually unchanged, reflecting the findings of the literature review, i.e. no effect.
- The mean speeds increased by on average 0.4 km/h (+0.8%), with the increases *significant* at the 0.05 test level for stn 324 and stn 1161 (See Table G7).
- The 85^{th} percentile speeds increased by on average 0.5 km/h (+0.9%), which is in line with the findings in the literature review, that narrower lanes do not automatically mean speeds are reduced.
- The site has been included in CAS as a "Site of Interest", but it is too early to determine whether any significant changes to the crash rates in the area have occurred.

Suggested further research

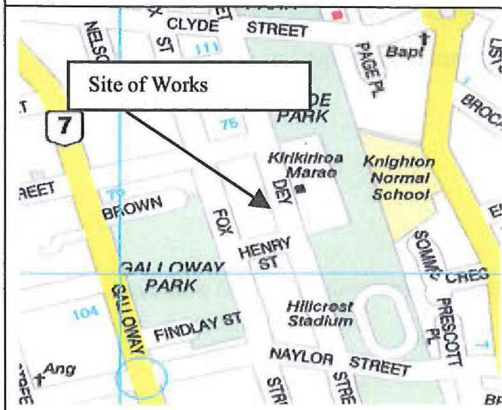
Further research could include:

- Monitoring traffic volumes, speeds and crashes thereby in assisting in determining the degree to which each impact is affected.

Slow point - Dey Street, Hamilton

Details of the scheme are outlined in the following table and Appendix H.

Table 4.19: Scheme Overview – Dey Street

Locality Plan	**'After' installation near No. 229 looking south**
	

Background		
The scheme involved the installation of two angled slow points, and a set of 1.6m wide asphaltic concrete road cushions, three abreast. The scheme was installed as it met Hamilton City Council's traffic calming warrant criteria, although they are unable to confirm why slow points were selected.	**Roadside development**	Residential (west), Undeveloped (east)
	Road hierarchy	Local
	Speed limit	50 km/h
	Carriageway width	9m
	Kerb side parking	Yes
	Gradient	Varies 1 – 2%
	Bus route	No
	Date devices installed	2002
	Device spacing	200 and 280m approx.

Post installation impact summary						
ADT (7 Day)	'Before' not assessed, 'After' 1790 (12/2005) between Cook and Wellington Streets					
Speed[1]	'Before' not assessed			'After' (12/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	-			40.9	37.3	41.0
• 85th percentile (km/h)				48.6	48.2	48.6
• Sample size				14801	217	14584
• SD (km/h)				8.1	12.1	8.0

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Hamilton City Council except the plan, http://www.wises.co.nz/)

[1]– Measured 10 – 15m north of the northernmost slow point, north of Wellington Street.

Installation

- Specific provision for cyclists has been provided.

- The 3.2m wide lane widths through the device, and is slightly more than recommended dimension of 2.8 – 3.0m (Austroads 2004).

Potential effects

- The 40.9 km/h mean speed 10m – 15m north of the slow point, suggests that the calculated path angle through the slow point has had minimal effect in slowing motorists. Analysis of north and southbound traffic highlights that the differences in mean and 85th percentile speeds are less than 2 km/h, further evidence of the slow point being less effective than it could potentially be.

Suggested further research

Further research could include:

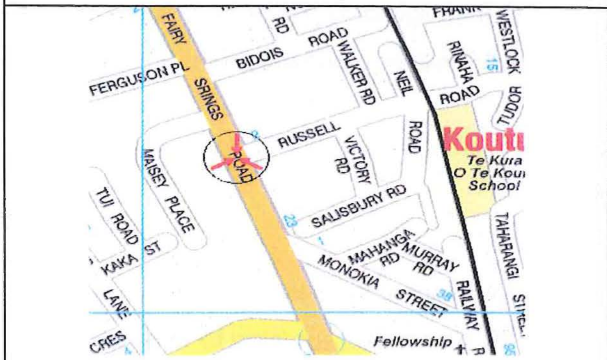
- Measuring the speeds through the slow point, and correlating these results with the actual path angle taken by motorists.

Slow point – Russell Road, Rotorua

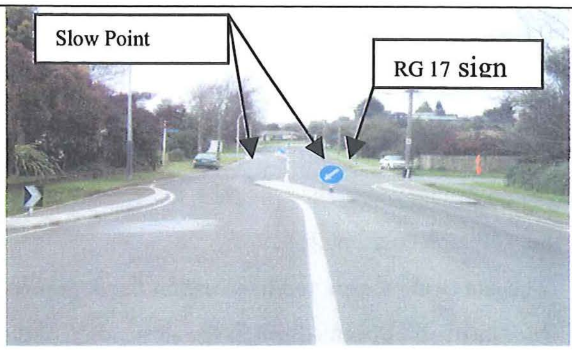
Details of the scheme are outlined in the following table and Appendix H.

Table 4.20: Scheme Overview – Russell Road

Locality Plan



'After' installation



Background		
The scheme included the installation of two angled slow points, a modified "T" intersection, and a median island.	**Roadside development**	Residential
	Road hierarchy	Local
	Speed limit	50 km/h
	Carriageway width	11m
	Kerb side parking	Yes
	Gradient	Approximately 1%
	Bus route	Yes
	Date devices installed	3/2003
	Device spacing	Varies, 90 - 120m

Post installation impact summary

ADT (7 Day)	Not assessed		
Speeds[1]	'Before' not assessed	'After'	
	All vehicles	North-westbound, (7/2005)	North-eastbound (7/2005)
• Mean (km/h)	-	47.8	47.2
• 85th percentile (km/h)		54	53.6
• Sample size		103	77
• SD (km/h)		6.0	5.9

Other comments

- Speed surveys undertaken using hand held radar gun

(Table based on information supplied by Rotorua District Council except the plan, http://www.wises.co.nz/)

[1] – Measured midway between the devices (angled slow point and modified "T" intersection) located opposite No. 14 and 23, 90m apart.

Installation

- It has not been verified whether specific provision for cyclists was considered during the design phase.
- The lane width though the slow points varies between 3 and 4m, and is slightly more than recommended dimension of 2.8 – 3.0m (Austroads 2004).

Potential effects

- RG 17 signs at the end of islands are constantly being replaced, due to damage by "boy racers".
- The mean 'after' speeds midway between the slow point, and the modified "T" intersection are significantly more than the values as listed in Table 3.20, and are approximately 6 km/h below the mean 2004 urban speed for Waikato, as listed in the Ministry of Transport's website (Appendix C). Furthermore, the path angle through the slow point is approximately 11^0, which could result in mean speeds approaching 48 km/h. These two factors combined with slightly wider widths than recommended, could be contributing factors to relatively high 'after' speeds.

Suggested further research

Further research could include:

- The site being monitored to ascertain the degree to which traffic volumes, and crashes are effected.
- Measuring the speeds through the slow point, and measuring the actual path angle taken by motorists.

Roundabout - Puriri Street, Hutt City

Details of the scheme are outlined in the following table and Appendix H.

Table 4.21: Scheme Overview – Puriri Street

'After' installation	'After' installation
	

Background

The scheme involved the construction of three roundabouts at each intersecting road on Puriri Street, which is approximately 430m long. Roundabouts were selected as the preferred device. Devices such as humps were deemed unsuitable for buses and HCV's and if installed could have had the effect of diverting traffic down 'local' residential streets.

Roadside development	Residential
Road hierarchy	Local Distributor
Speed limit	50 km/h
Carriageway width	9m
Kerb side parking	Restricted on one side
Gradient	Level
Bus route	No
Date devices installed	12/ 2000
Device spacing	Varies 190 – 240m

Post installation impact summary

ADT (7 Day): 'Before' 3749 vpd (9/1998), 'After' 3537 vpd (11 - 12/2001)

Speeds[1]	'Before' (9/1998)[2]			'After' (11 - 12/2001)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	53.7	53.8	50.4	41.5	41.7	36.9
• 85th percentile (km/h)	60.1	60.5	56.2	47.5	47.5	44.3
• Sample size	27848	26622	1226	32659	31404	1255
• SD (km/h)	7.4	7.4	6.2	6.3	6.2	7.0

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system.

(Table based on information supplied by Hutt City Council)

[1] – Measured approximately midway between Pohutukawa Street and Ngaio Crescent, 190m apart.

[2] – Pohutukawa Street was originally named Oxford Terrace.

Installation

- Other than the aerial photos, no construction details have been provided.

Potential effects

- Volumes are virtually unchanged, which is contrary to the findings of the literature review, i.e. a reduction.

- The 'after' speeds midway between the devices show a significant reduction in speed, and the 85th percentile speed of 54.1 km/h is less than that calculated using Eq. 2.
- The mean 'after' speed of 41.5 km/h midway between the roundabouts exceeds the maximum theoretical speed of 39 km/h. The maximum theoretical speed is based on a device speed through the roundabout of 19 km/h [Eq. 3, i.e. $6 * (10)^{1/2} = 19$ km/h] and a maximum speed differential of 20 km/h,
- The mean speeds decreased by one average 12.2 km/h (-22.7%), with the reductions *significant* at the 0.05 test level (See Table G7).
- The 85th percentile speeds decreased by on average 12.6% km/h (-21.1%).

Suggested Further Research

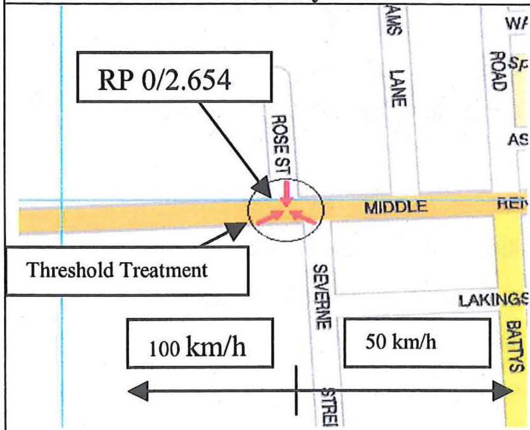
Further research could include:

- Measuring the speeds between the devices as part of a wider study to establish a speed/distance relationship, where the relationship may well depend on the approach mean speed which is governed by (Eq 3).

Perimeter threshold treatment - Springlands, Blenheim

Details of the scheme are outlined in the following table and Appendix H. The scheme has been included in this report to illustrate the effectiveness of a perimeter threshold treatment, while recognising that a treatment of this sort is unlikely to be implemented in a LATM.

Table 4.22: Scheme Overview - Springlands

Locality Plan	'After' installation looking east
	

Background	**Roadside development**	Rural/ Urban
The scheme involved installing an architecturally designed threshold treatment in response to motorists inability to slow down when entering the 50 km/h speed zone, and to complement the "beautification and promotional" exercise being undertaken by the local authority. Standard Transit NZ thresholds and surfacing treatments were considered, but rejected as it was unlikely that they would reduce speeds significantly.	**Road hierarchy**	State Highway
	Speed limit	100/50 km/h
	Carriageway width	10.5 – 11.1m
	Kerb side parking	None
	Gradient	Level
	Bus route	Yes
	Date devices installed	Early 2002
	Device spacing	22m

Post installation impact summary

ADT (7 Day)	Not assessed					
Speeds	No threshold installed[1] (6/2000)		Threshold installed[2] (2/2004)		Threshold installed[2] (8/2004)	
	Eastb'nd	Westb'nd	Eastb'nd	Westb'nd	Eastb'nd	Westb'nd
• Mean (km/h)	73	69	61	59	56	58
• 85[th] percentile (km/h)	85	79	69	66	62	62
• Sample size	110	123	100	100	100	100
• SD (km/h)	9.9	8.6	7.2	7.0	5.8	5.1

Other comments

- Speed surveys undertaken using hand held radar gun

(Table based on information supplied by Opus International Consultants except the plan, except http://www.wises.co.nz/)

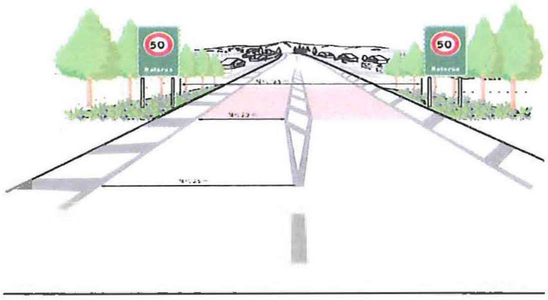
[1] – Measured at RP 0/2.600

[2] - Measured at RP 0/2.666 with the speed restriction signs relocated from RP 0/2.714 to the threshold at RP 0/2.832, a distance of 118m.

Installation

The installation differs from the standard Transit Threshold.

Fig 4.1: Typical Sign Layout (Transit Threshold)



Source: Transit New Zealand, 2001

Potential effects

- Prior to the installation of the threshold, earlier surveys had indicated that motorists commenced deceleration at the signed speed restriction, and continued with speeds in the 60 km\h to 70 km\h range until they approached the major crossroads some 480m to the east. Following installation of the threshold, speeds appeared to have reduced significantly at Rose St, approximately 70m east of the original speed restriction. Consequently no surveys were conducted east of that point, and surveys were continued at Rose St. No adverse comments have been received from pedestrians or cyclists.
- Mean speeds for eastbound traffic and westbound traffic decreased by 17 km/h and 11 km/h respectively, exceeding the typical reduction of 3.2 km/h as per the literature review. The reductions in speed are *significant* at the 0.05 test level (See Table G7). A significant amount of publicity by Transit NZ, the local council and the police is likely to have heavily influenced the reduction in speed by 'locals'.
- The results should be treated with a degree of caution given the small sample sets. Given the reduction in speed of westbound traffic, and that the threshold is aimed primarily at eastbound motorists, suggests another factor may be contributing to the reduction in speed.
- The crash rate is being monitored via CAS.

Suggested further research

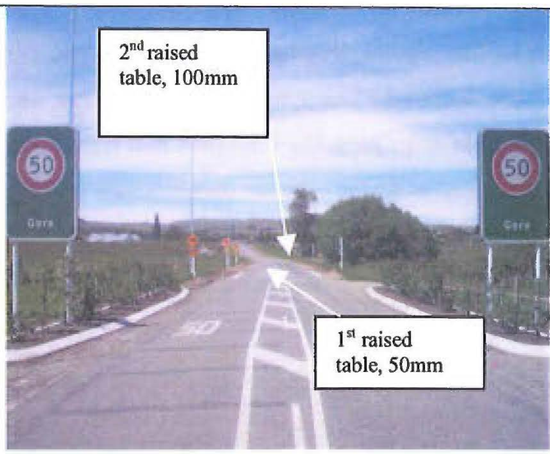
Further research could involve:

- Comparing the extent of the reduction at this site with other threshold treatments, and continuing monitoring the speeds to determine whether the speed reduction beyond the threshold has been maintained.

Perimeter threshold treatment - Woolwich Street, Gore

Details of the scheme are outlined in the following table and Appendix H. The scheme has been included in this report to illustrate the effectiveness of a perimeter threshold treatment, while recognising that a treatment of this sort is unlikely to be implemented in a LATM.

Table 4.23: Scheme Overview – Woolwich Street

'Before' eastbound approach,	'After' eastbound approach
	

Background

This scheme involved installing a perimeter threshold treatment, and raised tables, with the objective of slowing motorists to the point where their approach speeds matched the available approach sight distance (ASD) of 35m to the intersection obscured by the stop bank. An additional objective was to reduce the crash rate, eight involving south bound traffic in the period 1990 – 2003 incl. (Brazil, 2003).

Roadside development	Rural/ Urban
Road hierarchy	Rural Collector
Speed limit	100 km/h
Carriageway width	8m between kerb faces
Kerb side parking	Nil
Gradient	Level
Bus route	No
Date devices installed	8/2004
Device spacing	40m

Post installation impact summary

ADT (7 Day) South bound 'Before' – 129 vpd (7/2004), South bound 'After' – 143vpd (12/2004)

Speeds[1]	Threshold sign (6 – 7/2004)			Threshold sign plus humps (25 and 50mm high) (09/2004)			Threshold sign plus height of humps increased to 50 & 100mm (12/2004)		
	All	LCV's	HCV's	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	48.0	48.2	40.5	45.6	46.0	37.8	37.6	37.8	31.2
• 85th percentile (km/h)	58.7	58.7	47.9	56.5	56.9	44.3	46.1	46.1	40.3
• Sample size	1170	1141	29	716	683	33	1122	1083	39
• SD (km/h)	11.2	11.2	9.8	11.5	11.5	7.7	8.9	8.9	8.3

Other comments

- Speed surveys undertaken using the Metrocount ® vehicle classification system

(Table based on information supplied by MWH)

[1] – Measured at station 80, the original location of the speed restriction signs.

Installation

- The original proposal involved constructing three raised tables, one at the threshold and two beyond the threshold. Two raised tables (with 4m plateaus, 25 and 50mm high with 1 in 72 and 1 in 36 sloping ramps respectively) were constructed approximately 40m and 76m beyond the perimeter threshold treatment, and speeds monitored. Following evaluation of the initial results, the height of the raised tables was increased in height to 50 and 100mm, resulting in ramp gradients of 1 in 36 and 1 in 18 respectively. Further evaluation showed that the objective had been achieved, and installing the raised table at the threshold wasn't required. The 4m plateau lengths cater for cars (NZ design car, 2.65m between wheel bases) and not for trucks, a reflection of the low numbers using the route, i.e. < 5% of the total daily traffic volume.
- Rumble strips have been installed half way across the road, and may encourage motorists travelling towards the threshold to divert onto the opposite side of the road to avoid them, thereby increasing the risk of a "head on", albeit at low speed.
- MWH have confirmed that the low numbers of vehicles and cyclists deemed specific provision for cyclists as being unnecessary.

Potential effects

- Volumes have increased slightly but the results should be treated with caution given the small sample sets.
- The effects of noise and vibration are unlikely to affect residents given the nearest resident lives 200m south of the site.
- The 85th percentile 'after' approach speed is commensurate with an ASD of approximately 40m, as opposed to the 35m available.
- The mean speeds decreased by 10.4 km/h (-21.7%), with the reductions *significant* at the 0.05 test level (See Table G7).
- The 85th percentile speeds reduced by 12.6 km/h (-21.5%), and exceed the typical reduction of 3.2 km/h for thresholds as per the literature review, a function more likely of the raised tables, as opposed to the threshold itself.

Suggested Further Research

- Further research could include:
  - Measuring the level of compliance of motorists crossing the rumble strips and remaining on their side of the road, given they have been installed primarily for southbound traffic.
  - Checking for evidence of grounding at the 100mm high raised table.

4.1 Case Study Summary

4.1.1 Review of objectives

As stated previously the scope was altered to:

- Present the data collected in New Zealand as a series of case studies and comment on the differences between the case studies and the key findings of the literature review.
- Identify future opportunities for further research including:
  a. How data may be gathered, stored and distributed in New Zealand to facilitate access by all practitioners.
  b. For those devices identified during the literature review that conclusively reduce speed, list some unresolved issues that could be investigated to improve our understanding of how the devices work.
  c. Highlighting how New Zealand practice could be improved with respect installing traffic calming devices on 'local roads'.

This section covers the above points.

4.1.2 Data Collection

In addition to the problems highlighted in the methodology regarding the data collection, this was further compounded by:

- Very few RCA's referencing the RAMM position when undertaking surveys, therefore removing the reliance on general descriptions.
- Incomplete information being provided partly due to staff turnover.
- Few sites with similar types of treatments, allowing comparisons between sites to be made.

4.1.3 Case studies

The differences between the case studies, and the literature review is illustrated in Table 4.24.

Table 4.24: Differences between Literature Review and Case Studies

Literature Review Findings	**Case Study findings**
• **Watts profile road hump (Taunton Tce, Sierra St, Blackburn LATM, Waterfront Rd)**	
Device spacings of 80 to 120m recommended.	Waterfront, 130m. Blackburn, 166 – 260m.
Grounding – maximum height of 75mm.	All sites, Watts profile.
Traffic volumes - reduce by on average 24%.	Blackburn, reductions on average of –32.45 with the remaining sites not assessed.
Speed differential - Maintain recommended speed differential of 20 km/h between speed at device and midway between devices.	Blackburn, the speed differential appears likely to be exceeded.
Crash risk - Reported injury accidents may reduce by up to 65%.	No monitoring of accidents was undertaken at any site.
Monitoring of other impacts.	Nil.
• **Raised Table (Victor St, Konene St, Tuckers Rd)**	
Device spacings of 80 to 120m recommended.	Victor, 125 – 200m; Konene, 120 – 150m; Tuckers, 80 - 130m.
Grounding – maximum height of 75mm.	Raised tables at all sites were 100mm high.
Comfort - minimum ramp gradient 1 in 15.	Konene, 1 in 10 and Tuckers, 1 in 20 with the gradient subsequently increased.
Plateau length should correspond with the length of the design vehicle unless it is being used as a pedestrian crossing point.	Victor, No obvious reason for having a 6m long plateau, and not being used as a pedestrian crossing point.
Traffic volumes - reduce by on average 24%.	Tuckers, changes insignificant. Remaining sites not assessed
Device crossing speeds.	Not assessed.
Speed differential - Maintain recommended speed differential of 20 km/h between speed at device and midway between devices.	Tuckers, It is likely (but unconfirmed) that the recommended speed differential will be exceeded.
Monitoring of other impacts.	Konene, crash rate is being monitored.
• **Road Cushions (Rimu St, Ranui Ave, Waimarie St, Magnetic/Harrington St, Maitland St)**	
Device spacings of 80 to 120m recommended.	Rimu, 160–275; Waimarie, 210m; Magnetic/Harrington, 96-144m.
Remove parking with 10m of paired cushions.	Rimu and Magnetic/Harrington involve paired cushions without centre islands to ensure that motorists travelling in opposite directions do not share the same road space.
Install 1600 – 1700mm wide cushions on bus routes.	One site used as a bus route has 1900mm wide cushions installed. Waimarie/ Rimu, no reported problems.
Grounding – maximum height of 75mm.	Devices at all sites 75mm high.
Traffic volumes - reduce by on average 24%.	Four of the five sites reported reductions of between – 20 and 41%. Changes in volumes in Maitland Street, inconclusive.
Device crossing speeds.	Not assessed.

Table 4.24 (cont): Differences between the Literature Review and Case Studies

Literature Review Findings	**Case Study findings**
Road Cushions (Rimu St, Ranui Ave, Waimarie St, Magnetic/Harrington St, Maitland St)	
Speed differential - Maintain recommended speed differential of 20 km/h between speed at device and midway between devices.	Speed/spacing relationship using (Eq 10) doesn't work for Rimu, Ranui and Waimarie Streets noting that the road cushions in Ranui have a longitudinal Watts profile.
Monitoring of other impacts.	Crash rate at both sites is being monitored via CAS.
• **Centre Blister (Sunset Rd)**	
Device spacings of 80 to 120m recommended.	140m.
Install devices on 'local roads'.	The device has been installed on an arterial road.
Traffic volumes – variable	Not assessed.
Device crossing Speeds.	The mean speed of approximately 41 km/h though the centre blister is approximately 13 km/h higher than that for road cushions.
Monitoring of other impacts.	Nil.
• **Midblock Median (Goodwood Drive)**	
Traffic volumes – No effect.	Volumes increased by approximately 8%.
Speed reduction – Inconclusive.	The mean and 85th percentile speeds midway between devices reduced by between 2.2 and 3.8 km/h respectively.
Device crossing speeds.	Not assessed.
Monitoring of other impacts.	Nil.
Carriageway Narrowing (Thorrington Rd and Creyke Rd)	
Traffic volumes – No effect	Thorrington - Volumes reduced but this may be a result of motorists being required to take a longer route. Creyke - No effect.
Speed reduction – Length is the key parameter not width.	Thorrington - Speeds reduced in one direction only. Creyke - No effect.
Monitoring of other impacts.	Thorrington - Crash rate is being monitored.
Reduce Lane Width (North Rd)	
Traffic volumes – No effect.	Changes insignificant.
Speed reduction – Reduced lane width does not automatically result in a reduction in speeds.	Increases in speed of up to 0.8 km/h at two sites.
Monitoring of other impacts.	Crash rate being monitored via CAS.
Slow Point – Two Way (Dey St and Russell Rd)	
Device spacings of 80 to 120m recommended.	Dey St- 200m and 280m.
Traffic volumes – Reduce by up to 7%.	Not assessed.
Device crossing speeds (85th percentile speed between 32.2 to 40.2 km/h for path angles of 15^0- 20^0).	Dey - 40.9 km/h 10 – 15m north of northern most slow point. Russell - Path angle of approximately 11^0.
Speed differential - Maintain recommended speed differential of 20 km/h between speed at device and midway between devices.	Russell - Unlikely to be exceeded. However, the mean 'after' speeds midway between the two devices is only 6km/h less than the mean urban speed for the Waikato.
Monitoring of other impacts.	Nil

Table 4.24 (cont): Differences between Literature Review and Case Studies

Literature Review Findings	Case Study findings
Roundabout (Puriri St)	
Device spacing up to 140m.	190 – 240m.
Traffic volumes – Reduce.	Changes insignificant.
Speed Differential - Maintain recommended speed differential of 20 km/h between speed at device and midway between devices.	Exceeded.
Monitoring of other impacts.	Nil.
Perimeter Threshold Treatment (Springlands and Woolwich St)	
Rumble Strips	Installed halfway across the road.
Traffic volumes – no effect	Woolwich, 10.9% increase.
Speeds - reduce	Not assessed.
Monitoring of other impacts	Nil

In addition the effectiveness of each device in reducing speed is listed in the following table.

Table 4.25: Case studies – mid-device speeds.

Device	Speeds (km/h)		Device Spacing (m)	Notes
	Mean	85^{th} percentile		
Road cushion, 100mm	-12.8 (-25.0%)	-14.1 (-24.0%)	111	(A/C, Watts profile)
Roundabout	-12.2 (-22.7)	-12.6 (-21.1)	190 – 240	
Perimeter threshold	-10.4 to –14.0 (-19.7 to –21.7)	-12.6 to –20.0 (-21.5 to –24.4)		Results at one site may be heavily influenced by the installation of raised tables.
Carriageway narrowing	-9.8 (20.7)	- 11.1 (-19.0)		Reduce from 11m to 6m. Results may be influence by motorists have to turn left after having crossing the metrocount classifiers.
Raised table	-8.8 (-17.1%)	-10.1 (-17.0%)	130	
Road cushion, 75mm	-8.2 to - 14.4 (-17.3% to 28.7%)	-8.6 to –16.2 (-15.0% to – 27.5%)	86 – 96	
Road hump (Watts)	-6.0 (-14.4%)	-7.0 (-12.6%)	210	
Median island	-2.8 (-5.3)	-3.3 (-5.5)	64 - 107	
Carriageway narrowing	-2.8 (-6.5%)	-2.1 (-4.1%)	-	Reduce from 11m to 8m
Lane Narrowing	+ 1.3 (+2.7%)	+0.7 (+1.3%)		The effect on speed is unlikely to be seen for several years the trees in the berm grow and result in visual discomfort for drivers..

Note: Thresholds were omitted from the table as they are used in conjunction with other devices.

The results have to be treated with some caution but they do illustrate the vertical devices are the most effective in reducing speeds. No slow points were included in the analysis as 'before' and 'after' data wasn't available.

4.1.4 Speed/ spacing relationships

The speed/ spacing relationships are an important component of undertaking speed based design as (Austroads 2004).

Of the devices identified in the literature review, reliable speed/ spacing relationships have been developed formulated for:

- Circular humps, 75 and 100mm high (Table 3.20).
- Raised tables, 75mm high with ramp gradients between 1 in 10 and 1 in 15 (Table 3.20).
- Raised tables, 100mm high with ramp gradients between 1 in 8 and 1 in 10 (Table 3.20).
- Road cushions (Table 3.22).

Further research is required to establish speed/ spacing relationships for slow points.

The case studies found that that the speed/ spacing relationship as referred to in the literature review for:

- Circular humps appears to lie within the range specified in the literature review, consequently practioners can use these tables.
- Raised tables could not be confirmed.
- Road cushions appears to lie within the range specified in the literature review, consequently practioners can use these tables.

In addition a relationship (Eq's 11 and 12) was established for midblock medians, but the results should be treated with caution given the small sample sets.

Furthermore a number of RCA's have installed devices at spacings more than the recommended maximum, which is likely to result in the speed profile for the street exceeding the 20 km/h recommended maximum speed differential.

4.1.5 Further research

Further research could be undertaken to clarify some outstanding issues using the case studies contained within this. The details of these are included in each case study summary. In undertaking this research it is apparent that the focus should be on a few devices as opposed to a large range of devices, the reason being is that the volume of information or lack of it make its difficult to remain focussed on the objective and to be able to make firm conclusions.

5. CONCLUSIONS

5.1 General

Conclusions resulting from this report are:

- The research objectives were achieved, other than the production of a design guide. Insufficient information exists to produce a design guide as:
  - Only a few devices exists for which strong evidence exists with respect to their effectiveness in reducing speed and the resultant effects (Table 3.26).
  - Several other devices exist which are used in New Zealand (Table 3.27), but require further investigation in order to assess their effects.
- When installing traffic calming devices as part of an LATM, practitioners need to understand several key aspects:
  - How they work.
  - The resultant effects and magnitude of those effects, i.e. not that speed reduces, but by how much.
- Limited information exists within New Zealand that practitioners can readily access when planning and designing LATM schemes, such that they can have confidence in the solution they propose to install and undertake 'speed based' design (Austroads 2004).

5.2 Literature Review

The literature review has highlighted that:

- Minimal research has been undertaken in New Zealand with respect to LATM schemes.
- The devices supported by strong evidence that conclusively reduce speed, and the resultant effects include the following devices, although some issues still require resolving (Table 3.26 and Section 3.10).
  - Raised Tables
  - Circular Humps
  - Road Cushions
  - Slow Points
  - Perimeter Threshold treatments
- A limited amount of information exists regarding the effects of a number of devices in common used in New Zealand and further research is recommended (Table 3.27).
- Reliable speed/ spacing relationships exist for a number of devices (circular humps, raised tables and speed cushions) that can be used by practitioners, but do not exist for other devices in common use, e.g. slow points.
- Speed based design is limited to a few devices.
- The maximum height of any device should not exceed 75mm, in order to minimise the likelihood of grounding.
- Devices can be constructed on gradients, but more information needs to be obtained prior to preparing a design guide.
- The plateau length of raised tables should be long enough to cater for the design vehicle.
- While international research is being carried, some devices do not appear to have found favour in New Zealand, e.g. road depressions.
- Several good websites exist overseas, as listed in Appendix C.

5.3 Case Studies

The case studies have highlighted that:

- The low response rate from RCA's meant that the conclusions reached in this report are based on a very small sample.
- The mobility of staff within RCA's gives further weight to the argument that a design guide is produced so the industry can retain the collective knowledge.
- Virtually all sites could have benefited from some additional input at the design stage.
- Device spacings often exceed the recommended guidelines, casting into doubt whether or not the design speed differential will be achieved.
- Devices are still being installed higher than 75mm high, increasing the likelihood of grounding.
- Minimal monitoring is being undertaken to assess the effectiveness of the device and the resultant impacts, and where it is undertaken a variety of approaches are undertaken, few with any commonality. In addition, monitoring could be improved easily to ensure commonality between RCA's, e.g. record 'before' and 'after' surveys using RAMM stations.
- Of the 21schemes, 10 resulted in a statistically significant reduction in speed, while 2 resulted in a statistically significant increase in speeds.
- The two schemes that were ineffective at this stage in reducing speed (e.g. carriageway narrowing and lane reduction), but may well be worth implementing at other sites due to the other resultant benefits, e.g. crash reduction.
- While traditional traffic calming treatments are being applied to 'local' roads, traffic calming is starting to be applied to arterial roads in New Zealand.
- Innovative treatments are being installed, e.g. the 'three abreast' midblock median island treatment being undertaken in Goodwood Drive.
- Any study that is carried out in the future should either focus on a longer time period, in order to take advantage of the planning process from the initial investigation to eventual construction, or focus on a few devices.

6. FURTHER STUDY RECOMMENDATIONS

It is recommended that Land Transport New Zealand action the recommendations contained in RSS 21 on the proviso that:

1. The study is undertaken over a three year period, in order to obtain sufficient information enabling firm conclusions to be drawn, and to avoid the problems associated with the short time period over which this report was prepared.
2. The focus is primarily on the devices listed in section 5, but may also include other devices that result in speeds reducing by diverting or reducing the volume of traffic including:
   - Blister Islands
   - Kerb Extensions
   - Parking
   - Mid-block Medians
   - Reduced lane width
   - Carriageway narrowing.
3. A standard form similar to the one contained in Appendix B is used, to assist with information being produced in a consistent manner.
4. A 'traffic calming' website and discussion group is set up similar to that on the ITE website and run in a manner similar to Signal Users NZ User Group (SNUG).
5. Key contacts are maintained and updated, possibly through the Traffic Manager's Liaison Group meetings facilitated by Land Transport New Zealand.
6. Liaison is undertaken with Austroads to avoid duplication of effort.
7. Investigate the key issues (e.g. humps on grades and peak vertical acceleration, device crossing speeds, 85th percentile speeds between devices) that are unresolved, but are associated with the devices that conclusively reduce speeds. Much of this information could probably be readily sourced from schemes that already exist, or are planned for in the future. In addition, the key research organisations could be contacted to ensure that work on the unresolved issues is not in the process of being completed.
8. Funding is provided to assist with the research.
9. Encourage innovation, but ensure that that monitoring is undertaken as outlined in 1.

Any design guide that is produced should be specific, and limit itself to the key issues and effects.

Further recommendations include:

- Practioners may wish to continue research into schemes that were in the process of being implemented, but were not included in this report due to time constraints (Refer to section 2.1).
- Researching community acceptability of devices, as this is a key factor in implementing a successful LATM.
- Research good design practice such that roads in new developments do not have to be 'traffic calmed' at a later date.

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8. APPENDICES

Appendix A: Research Proposal

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF CANTERBURY

ENTR 681 RESEARCH PROPOSAL
PART TIME MET PROJECT

"THE EVALUATION OF THE EFFECTIVENESS OF TRAFFIC CALMING DEVICES IN NEW ZEALAND IN REDUCING SPEEDS ON "LOCAL" URBAN ROADS"

Candidate: Ron Minnema (0251835)
Supervisors: Associate Professor Alan Nicholson/ Glen Koorey

ABSTRACT

"The objective of this research is produce a design guide of traffic calming devices that are effective in reducing the speeds of traffic on mid-block urban 'local' roads. Information exists on how to consult with the community when considering installing a Local Area Traffic Management Scheme but limited information exists on devices used in New Zealand and their effectiveness in reducing speeds. This work will be achieved by a combination of literature review, field surveys, data collection at relevant sites and analysis. The research will be completed by April 2006."

INTRODUCTION

Road Controlling Authorities' (RCA's) field numerous complaints from the public regarding motorists travelling at alleged excessive speeds on 'local' residential streets/roads, ie whose primary function is to provide access to properties. RCA's may decide that a Local Area Traffic Management Scheme (LATM) should be developed in consultation with the local community.

New Zealand practice with regard to traffic engineering (standards and approaches) is closely aligned to that in Australia. Appendix D of the Austroads' publication Part 10: Local Area Traffic Management (1998) provides an overview of the process and design principles that can be used to enable devices to achieve their objectives in an LATM and lists key principles including:

- Streetscape
- Location of Devices/Changes
- Design Vehicles
- Control of Vehicle Speeds
- Visibility Requirements
- Parking Provision

Vehicle speeds can be controlled by shifting vehicle paths laterally by using slow points, roundabouts, corners or vertically by constructing 'speed humps', intersection or pedestrian platforms. While various publications have been issued listing different devices that are available there does not appear to be a publication that provides guidance on when the devices should be installed and their effectiveness in reducing speeds.

OBJECTIVES

The objective of this research is to produce:

- A design guide of traffic calming devices that are effective in reducing the speeds of traffic on mid-block urban 'local' roads.
- A Masters of Engineering Project

METHODOLOGY

The research project shall consist of the following steps:

1. Data Collection

Given that construction of traffic calming devices may occur at various times throughout the year, depending on the location, it is imperative that all RCA's are contacted early in 2005 and invited to assist with the project prior to the literature review commencing. While the range of available devices will not be known all participants will be invited to assist with:

- Collecting data relating to 'before' and 'after' speed surveys, using where possible, standardised equipment and methodology.
- Collecting information relating to road environment, Annual Average Daily Traffic, key road characteristics, speed zone, spacing between devices, key dimension of the devices, grade and adjacent roadside development.
- Undertaking speed surveys at sites where no 'before' surveys have been undertaken.

Priority will need to be given, ensuring that participants undertake the 'before' surveys prior to the construction of the traffic calming devices commencing, whereas the remaining information can be provided at a later date.

2. Review of relevant literature

The review will involve:

- Researching information that has been published relating to traffic calming devices which have been used mid-block on local roads in New Zealand, Australia, United Kingdom and Europe. This will include publications, reports, policy and standard drawings.
- Undertaking a library search of relevant publications using on-line databases such as 'TRIS', 'scholar.google'.

This will be achieved by:

- Contacting Road Controlling Authorities, Suppliers of traffic control equipment, Research Organisations including Land Transport New Zealand.
- Searching websites of organisations to ascertain what information is available.

Survey forms will be sent out to participating RCA's, including a section indicating which devices they have installed on roads under their jurisdiction.

3. Data Analysis

For sites where traffic calming devices have been installed and where:

- Speed surveys were undertaken prior to the devices installation and results of the 'after' survey will be compared to the 'before' survey and the expected results as outlined in the literature research, ie the reduction in speed including the speeds of vehicles immediately past/or between similar devices.
- No speed surveys were undertaken prior to the devices installation and results of the 'after' survey will be compared to the expected results as outlined in the literature research, ie the speeds of vehicles immediately past/or between similar devices.

In addition, supporting information will be tabulated including key dimensions, features and photos.

4. Project Outputs

The primary outputs will be a design guide that will include:

- A list of devices that have been used on local roads in New Zealand and their effectiveness in reducing speeds midblock.
- Key features of those devices.
- Factors that need to be considered when deciding which devices may be appropriate for installation.

- Locations where the devices were installed including a description of the adjacent road environment including traffic volumes.
- Advantages and disadvantages of each device.

RESOURCES

The required resources will involve the speeds being measured by classifiers using wherever possible Metrocount Traffic Executive using the Austroads classification of vehicle types. It is envisaged that the cost for these tests will be borne by the respective RCA'S who are willing to assist, noting that the cost of performing before and after tests (estimated to be less than $300 per test) could be insignificant with respect to their overall programme.

Dunedin City Council will absorb the costs of additional surveys undertaken at sites under their jurisdiction into their annual traffic counting programme. Should surveys be undertaken at remote sites, Dunedin City Council may be willing to pay for this from their professional services budget. If not, applications for funding would be lodged with other sources such as IPENZ-TG post graduate assistance fund and the Engineering department's research fund.

TIME FRAME

The estimated time frame is as follows:

No	Activity	Estimated Completion Date
1	Data Collection	30/02/05 to 30/09/05
2	Scientific Literature Journal Search	30/04/05
3	Survey Analysis	30/11/05
4	Complete first draft of project report	30/01/06
5	Complete project revisions	30/03/06

REFERENCES

Austroads (1988), Guide to Traffic Engineering Practice, Part 10 – Local Area Traffic Management

- *Please complete all boxes with displayed and refer to Pages 7 and 8 for explanatory notes relating to some items.*
- *Either return the completed form electronically, or via hardcopy.*
- *If in doubt, skip that part of the form, or contact Ron Minnema, Ph 03 474-3706 or via e-mail rminnema@clear.net.nz*

1 - Site Description (General)			
1.1 - Road Name		**1.2** - 5 Day 24 Hr ADT (vpd)	
1.3 - Road ID ex RAMM		**1.4** - % Heavies (> 3.5t)	
1.5 - Road Section RP Start		**1.6** - Designated Bus Route (Yes/ No)	
1.7 - Road Section RP End		**1.8** - Designated Cycle Route (Yes/ No)	
1.9 - Physical Works RP Start		**1.10** - Posted Speed Limit (km/h)	
1.11 - Physical Works RP End		**1.12** - Grade %	
2 - Site Description (Specifics)			
2.1 - Schematic Plan, prior to the installation of traffic calming devices			
2.2 - Prior to the installation of traffic calming devices ***(Complete tables 2.2.1 and 2.2.2)***			

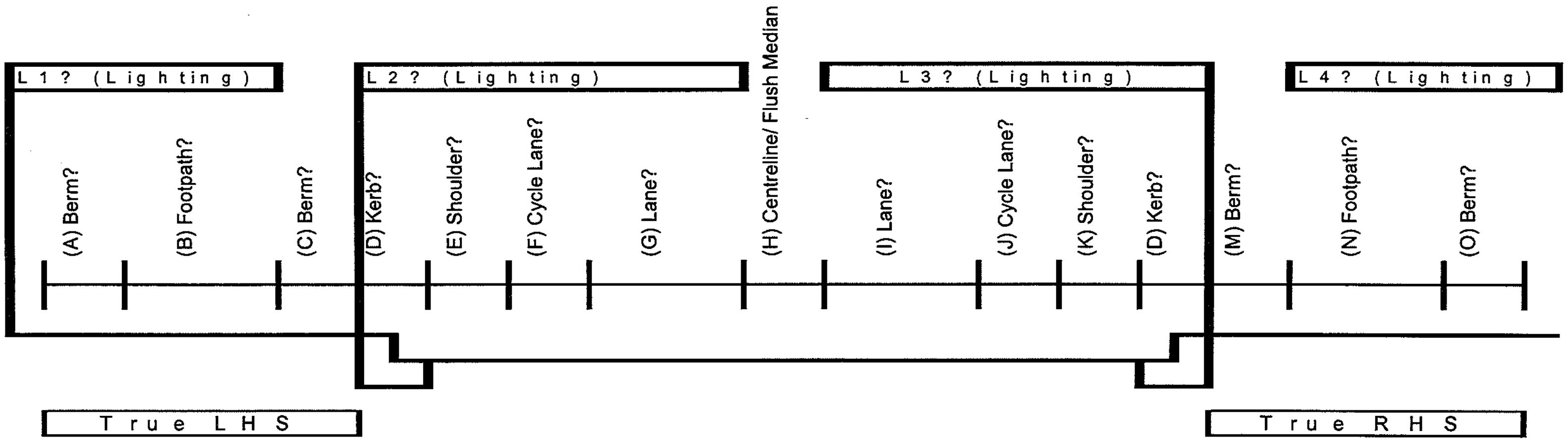
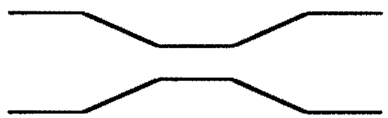


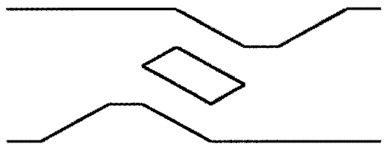
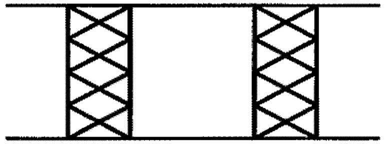
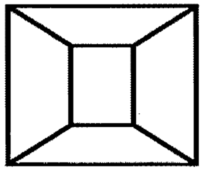
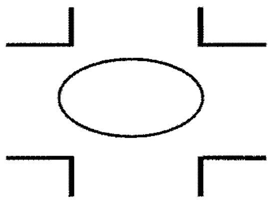
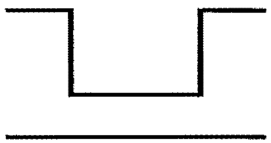
Table 2.2.1 – Typical Cross Section

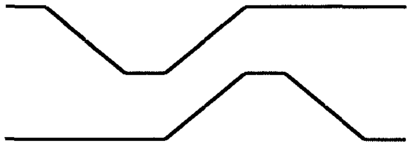
	True LHS								True RHS						
Item	***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***K***	***D***	***M***	***N***	***O***
Width (m)															

Table 2.2.2 - ***Miscellaneous***

Item	**True LHS**		**True RHS**	
2.3.1 – **Parking** ***Parallel/Angle?***				
2.3.2 – **Lighting** *Category P3, P4, P5?/Nil/Other*	L1		L3	
	L2		L4	
2.3.3 - (D) *Kerb and Channel/ sealed Water Channel/Other?*				
2.3.4 - Adjacent Roadside Development *Residential/Commercial/Other(State)*				
3 - Reason for Implementing Traffic Calming Scheme				
2.3.5 - No. of accesses between physical works start and end				
4 - Traffic Calming Devices				

4.1 **Treatment Option Description**	4.2 **Treatment Option Illustrated**	4.3 **Approximate RP where treatment option installed**	4.4 **Treatment Installation Date** ***(Month/ Year)***	4.5 **Illustrated by Construction Drawing No?**	4.6 **Photos included** ***(Include ref no.)***
Roadway Narrowing					

Angled Slow Point					
Platform					
Speed Cushion					
Mini Roundabouts					
Partial Road Closures					

Chicanes					
Other	***Complete as required***				

5 - Classified Traffic Survey Details *(Undertaken ideally midway between devices at the following RP's)*

5.2 **5 Day ADT** ***(Before/After)***	5.3– **Mean Speed** ***(Before/After)***	5.4 **85th %ile Speed** ***(Before/After)***	5.5– **Standard Deviation** ***(Before/After)***	5.6– **File Name** ***(metrocount/ Other/ hardcopy)***	5.7- **Survey Date** ***(month/ year)***	5.8- **Weather Conditions** ***(dry/wet/ ice/snow)***	5.9 **Temporary Road Works** ***(Yes/No)***	5.10- **Unusual Events**

- Checklist *(Complete as required)*

6.1 - **Survey form completed**	
6.2 - **Design Drawings Included *(prefer as PDF file)***	
6.3 - **Traffic survey files e-mailed**	
6.4 - **Traffic survey files sent via hardcopy**	
6.5 - **Photos sent**	
6.6 - **Aerial photo or map of site**	
6.7 - **Contact details confirmed updated**	
- **Name of key contact person**	
- **Designation**	
- **Phone Number**	
- **Fax Number**	
- **Email address**	

7 – Miscellaneous. Include any comments re intangibles that may be relevant.

Appendix C: Website Summary

- American Association of State Highway and Transportation Organisations (ASSHTO) (http://www.transportation1.org/aashtonew/)
- ARRB Transport Research (http://www.arrb.com.au/)
- Australian Association of Road and Traffic Authorities (http://www.austroads.com.au/)
- Institute of Transportation Engineers (http://www.ite.org/)
- Land Transport New Zealand (http://www.landtransport.govt.nz/)
- Scholar.Google (http://scholar.google.com/)
- Transit New Zealand (http://www.transit.govt.nz/)
- Transport Connect (http://www.elsevier.com/)
- Transportation Research Board (http://trb.org/)
- Transportation Research Laboratory (http://www.trl.co.uk/)
- UK Highways Agency (http://www.highways.gov.uk/)
- UK Department for Transport (http://www.dft.gov.uk/)
- University of Engineering – Transportation Portal (http://library.canterbury.ac.nz/eng/entr/)
- US Federal Highway Administrations (http://www.fhwa.dot.gov/)
- Speed statistics - MOT website (http://www.transport.govt.nz/business/land/research/speed2.php

Appendix D: Typical vehicle track widths (USA)

Vehicle	Average Track Width (ft)	Average Track Width (m)
Private Vehicle – Low[1]	4 ft. 2 in.	1.27
Private Vehicle – Medium[1]	4 ft. 11 in.	1.50
Private Vehicle – High[1]	5 ft. 9 in.	1.75
Typical Portland Fire Engine	6 ft. 5 in.	1.96
Typical Portland Aerial LADDER truck	6 ft. 7 in.	2.01
Typical Portland Rear- Tiller Truck	6 ft. 0in.	2.03
Typical Tri-met Transit Bus	6 ft. 3 in.	1.91

(Source: Batson, 2004)

Note

[1] – NHTSA inertia database available at: www-nrd.nhtsa.dot.gov/vrtc/ca/Cadata.htm

Appendix E: Road Cushions - formulae

Furthermore, Layfield & Parry (1998) formulated two equations linking the variables that influenced the mean and 85th percentile speeds at the cushions, i.e.

Table E1: Formulae @ Road Cushions

Mean Speed	**85th percentile Speed**
$V_{mm(at)} = A - B*w + C*L + D*V_{mm\ (bef)}$	$V_{85(at)} = E - F*w + G*L + H*V_{85\ (bef)}$
Where $V_{mm(at)}$ = mean speed at cushions	$V_{mm(at)}$ = 85th percentile speed at cushions
$V_{mm\ (bef)}$ = mean speed "before"	$V_{mm\ (bef)}$ = 85th percentile "before " speed
w = cushion width (mm)	w = cushion width (mm)
L = cushion length (mm)	L = cushion length (mm)
The variables (mean speed 'before', cushion width and cushion length) were statistically significant at the 1% level.	The variable cushion width was statistically significant at the 1% level, cushion length and 85th percentile 'before' speed were significant at the 5% level.

(Based on Layfield & Parry, 1988)

The constants (A – H) to obtain $V_{mm(at)}$ and $V_{85(at)}$ in mph and km/h are listed in the following table

Table E2: Mean speed at cushions - variables

Variable	A	B	C	D
mph	24.9	0.0134	0.00253	0.321
km/h	40	0.0215	0.00407	0.516

Table E3: 85th percentile speed at cushions - variables

Variable	E	F	G	H
mph	36.8	0.0185	0.00179	0.370
km/h	59.1	0.02973	0.00288	0.595

Appendix F

Table F1: Device Summary – Not recommended for further investigation[1]

Device	Further investigation recommended
14 foot long humps	No, given the difficulty in constructing humps with parabolic profiles and the fact that 75mm high circular humps serve a similar function successfully.
Sinusoidal	No, given the difficulty in constructing humps with parabolic profiles and the fact that 75mm high circular humps serve a similar function successfully.
Courtesy Crossings	No, given the design should be based on 'raised table' design parameters.
Raised Crosswalk	No, given the design should be based on 'raised table' design parameters.
'Wombat' Crossing	No, given the design should be based on 'raised table' design parameters.
'Gwinnett"	No, given the 85th %ile speeds are significantly higher than the raised table in Table 3.17, suggesting they may be more appropriate for 'collector' roads.
'S' Hump	No, given the difficulty in construction, limited use and that the 85th %ile speeds are significantly higher than the raised table in Table 3.17, suggesting they may be more appropriate for 'collector' roads.
Offset speed table	No, given the device has been developed to assist emergency areas where LATMs have been implemented.
Road Depression	No, given the limited use worldwide and the associated safety and maintenance issues.
Impellor	No, given the primary function of this device is safety.
Driveway links	No, given the design of the device is a function of geometric design and is well covered in Austroads (2004).
Roundabouts	No, given formula exist regarding operating speeds and the speed profile is likely to be more related to device spacing.
Mini-roundabouts	No, these devices are generally used in Central Business districts as opposed to local roads.
Give Way signs	No, given their zone of influence is likely to be less than all way 'stop' signs
Pedestrian Crossings	No, given pedestrians crossings are not routinely installed on 'local' roads.
Transverse Rumble strips	No, given the primary function of the device is to alert drivers as opposed to physically slowing traffic.
Road Roughness	No, given the expense and the resultant reduction in speeds precludes this as an option.
Rumblewave	No, given the primary function of the device is to alert drivers as opposed to physically slowing traffic.
Modified 'tee' intersection	No, given the principle of design should be based on that adopted for Slow Points.

[1] –At this time

Appendix G: Speed Survey Summaries

Table G1: Goodwood Drive – Outside No. 8 and 19, approx. 60m east of set 1 where sets 1 and 2 are 107m apart

Category	All vehicles – 'Before', 5001 (5/2005)			All vehicles – 'After', 5457 (12/2005)		
	All	HCV	LCV	All	LCV	HCV
Mean (km/h)	54.8	53.0	54.8	52.8	52.9	49.6
85^{th} %ile (km/h)	61.9	60.5	61.9	59.4	59.4	58
Sample size	36465	520	35945	38196	-	-
SD (km/h)	7.9	9.2	7.9	7.7	7.6	9.4

(Source: Opus International Consultants, Paeroa)

Table G2: Goodwood Drive – Outside No. 16 and 29a, approx. 40m east of set 2, where sets 2 and 3 are 64m apart

Category	All Vehicles – 'Before' 4797, (5/2005)			All Vehicles – 'After', 5172 (12/2005)		
	All	HCV	LCV	All	LCV	HCV
Mean (km/h)	50.6	47.7	50.6	47.2	47.3	44.5
85^{th} %ile (km/h)	56.5	55.4	56.5	53.3	53.3	52.6
Sample size	34940	534	34406	36207	-	-
SD (km/h)	6.7	8.3	6.6	6.7	6.6	8.4

(Source: Opus International Consultants, Paeroa)

Table G3: Goodwood Drive - Outside No. 35, approx. 40m east of set 3, where sets 3 and 4 are 87m apart

Category	All Vehicles – 'Before', 4763 (5/2005)			All Vehicles – 'After', 5142 (12/2005)		
	All	HCV	LCV	All	LCV	HCV
Mean (km/h)	53.4	50.1	53.4	50.3	50.3	47
85^{th} %ile (km/h)	60.1	58.3	60.1	56.9	56.9	55.4
Sample size	34646	498	34148	35996	-	-
SD (km/h)	7.7	9.0	7.6	7.5	7.5	9.5

(Source: Opus International Consultants, Paeroa)

Table G4: Creyke Road, opposite no. 24 east of Forestry Road

Speeds	Before (03 - 4/2003)			After (6/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	47.6	47.6	44.8	49.7	49.8	46.3
• 85^{th} %ile (km/h)	54.0	54.0	51.5	55.1	55.1	52.9
• Sample size	114584	113353	1231	98026	96880	1146
• SD (km/h)	7.6	7.6	8.0	6.8	6.7	9.5

(Source: Christchurch City Council)

Table G5: Creyke Road, opposite no. 48/50 Forestry Road

Speeds	Before (8/2001)			After (6/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	48.7	48.7	44.7	49.7	49.7	49.5
• 85^{th} %ile (km/h)	54.7	54.7	51.8	55.4	55.4	54.7
• Sample size	106451	105413	1038	101909	100659	1250
• SD (km/h)	7.2	7.1	8.6	7.2	7.0	16.0

(Source: Christchurch City Council)

Table G6: Creyke Road, opposite no. 88 west of Barlow Street

Speeds	Before (3 - 04/2003)			After (6/2005)		
	All	LCV's	HCV's	All	LCV's	HCV's
• Mean (km/h)	48.4	48.4	45.2	48.6	48.6	45.8
• 85^{th} %ile (km/h)	54.0	54.0	51.5	54.0	54.0	51.5
• Sample size	103016	101774	1242	94755	93572	1183
• SD (km/h)	6.7	6.7	7.8	6.7	6.7	8.9

(Source: Christchurch City Council)

Table G7: Tests of Significance

Location		Mean		Sample size		S.D		S.D. (x1 – x2) $^{1/2}$	t	Degrees Freedom	Significant	Speed change	
		before	after	before	after	before	after					Dec	Inc
Blackburn	opp no. 24	47	37.4	4053	4374	11.3	8.6	0.220031965	43.6	8425	Yes	Yes	
	opp no. 56	44.4	40.8	3539	1498	11.8	11.8	0.363723863	9.9	5035	Yes	Yes	
Tuckers	opp. No 35/37	51.4	42.6	16885	22688	9.2	7.6	0.086940051	101.2	39571	Yes	Yes	
Ranui	stn 290	51.1	38.3	24135	15629	8.3	6.8	0.076242793	167.9	39762	Yes	Yes	
Magnetic	Stn 172	47.3	39.1	4083	3260	11.1	9.8	0.244205781	33.6	7341	Yes	Yes	
Maitland	stn 543	50.1	35.7	11019	13506	13.2	7.5	0.141341794	101.9	24523	Yes	Yes	
Goodwood	opp no. 8 & 19	54.8	52.8	36465	38196	7.9	7.7	0.057129335	35.0	74659	Yes	Yes	
	opp no. 16 & 29a	50.6	47.2	34940	36207	6.7	6.7	0.050245292	67.7	71145	Yes	Yes	
	opp no. 35	53.4	50.3	34646	35996	7.7	7.5	0.057218723	54.2	70640	Yes	Yes	
Thorrington	opp no. 32 (e'bnd)	43.4	40.6	5170	2088	8.7	8.8	0.227438683	12.3	7256	Yes	Yes	
	opp no. 32 (w'bnd)	47.3	37.5	2636	1001	11.8	10.7	0.408898621	24.0	3635	Yes	Yes	
Creyke	opp no. 24	47.6	49.7	114584	98026	7.6	6.8	0.031237732	-67.2	212608	Yes		Yes
	opp no. 48/50	48.7	49.7	106451	101909	7.2	7.2	0.031554298	-31.7	208358	Yes		Yes
	opp no. 88	48.4	48.6	103016	94755	6.7	6.7	0.030158011	-6.6	197769	Yes		Yes
North Rd	stn 324	47.7	47.8	20451	81987	5.9	6.2	0.046593691	-2.1	102436	Yes		Yes
	stn 1161	48.4	49.2	15991	58646	7.2	6.4	0.062771422	-12.7	74635	Yes		Yes
Puriri	midway	53.7	41.5	27848	32659	7.4	6.3	0.056406331	216.3	60505	Yes		
Springlands	RP 0/2.666	61	56	100	100	7.2	5.8	0.924553947	5.4	198	Yes	Yes	
Woolwich	stn 80	48	37.6	1170	1122	11.2	8.9	0.421676207	24.7	2290	Yes	Yes	

The differences in means have been calculated as follows.

$$U_{x1-x2} = 0 \text{ and } S.D._{x1-x2} = \frac{S.D_1^2}{N_1} + \frac{S.D_2^2}{N_2} = S.D.\,(x1 - x2)^{1/2} \quad \text{AND} \quad z = \frac{x1 - x2}{S.D.\,(x1 - x2)^{1/2}}$$

Notes

1. Given the degrees of freedom are all very large, the critical t-value (5%, one-tail test) is 1.645.
2. Since all the t-values are greater than +1.645, or less than –1.645, all the changes are statistically significant..
3. The positive/ negative t-values indicate a speed decrease/ increase respectively.

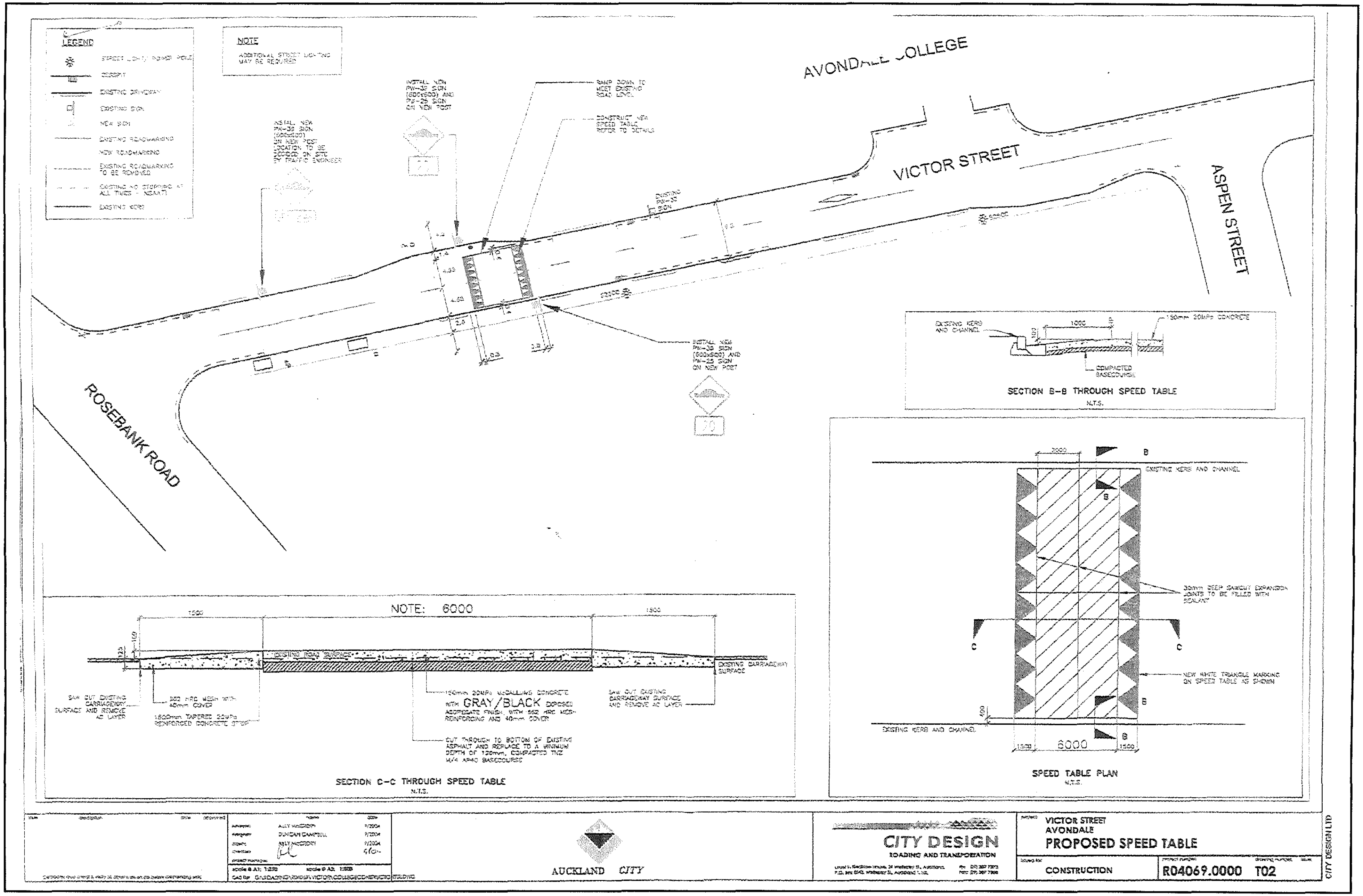
Appendix H: Site Plans

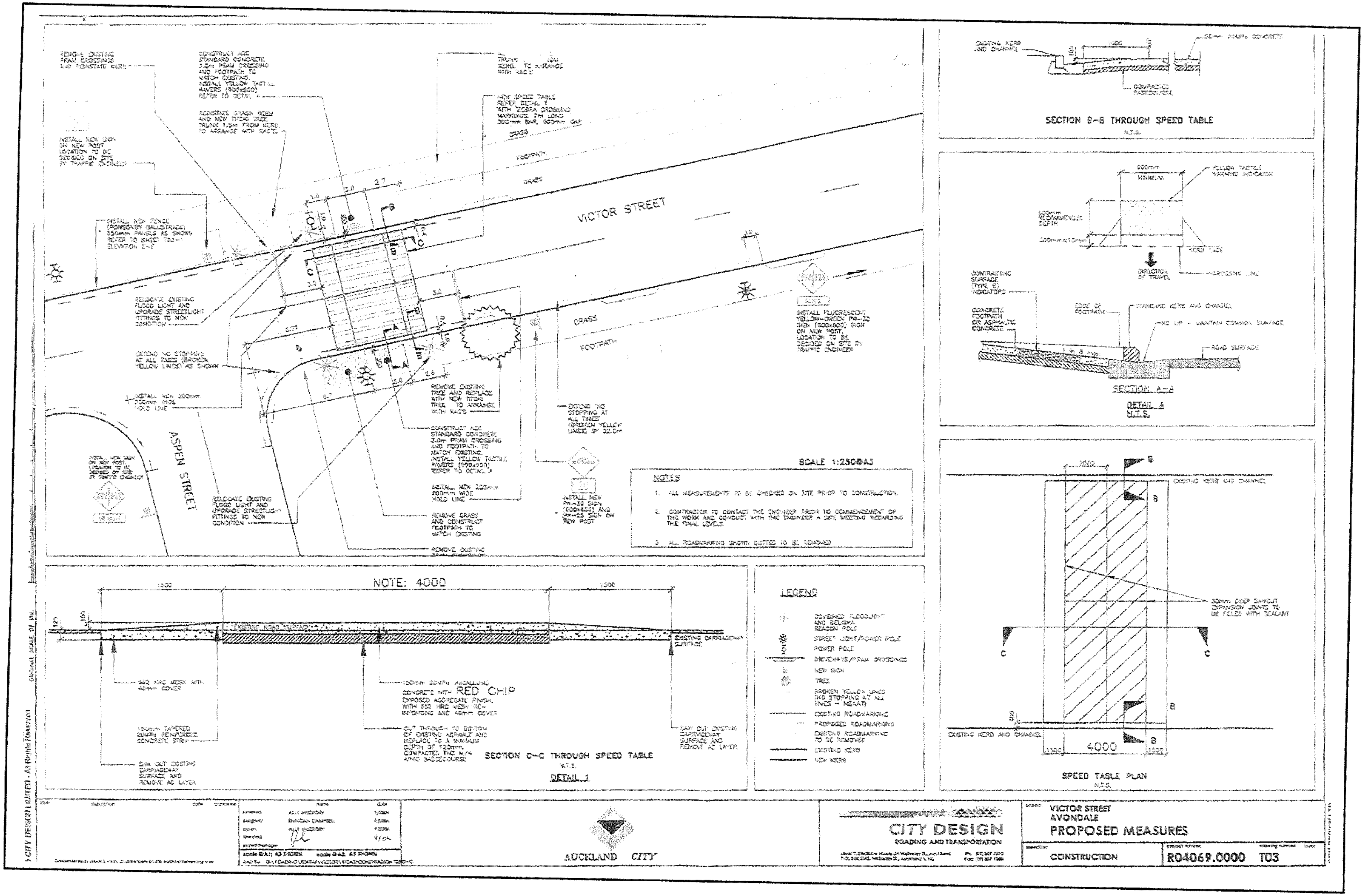
- Taunton Terrace, Auckland
- Blackburn LATM, Hamilton
- Victor Street, Auckland
- Konene Street, Rotorua
- Tuckers Road, Christchurch
- Rimu Street, Hamilton
- Ranui Avenue, Timaru
- Waimarie Street, Hamilton
- Magnetic Street/ Harrington Street, Dunedin
- Maitland Street, Dunedin
- Sunset Road, Rotorua
- Goodwood Drive, Manukau City
- Thorrington Road, Christchurch
- Creyke Road, Christchurch
- Dey Street, Hamilton
- Russell Road, Rotorua
- Puriri Street, Hutt City
- Springlands, Blenheim
- Woolwich Street, Gore

Taunton Terrace – Plan

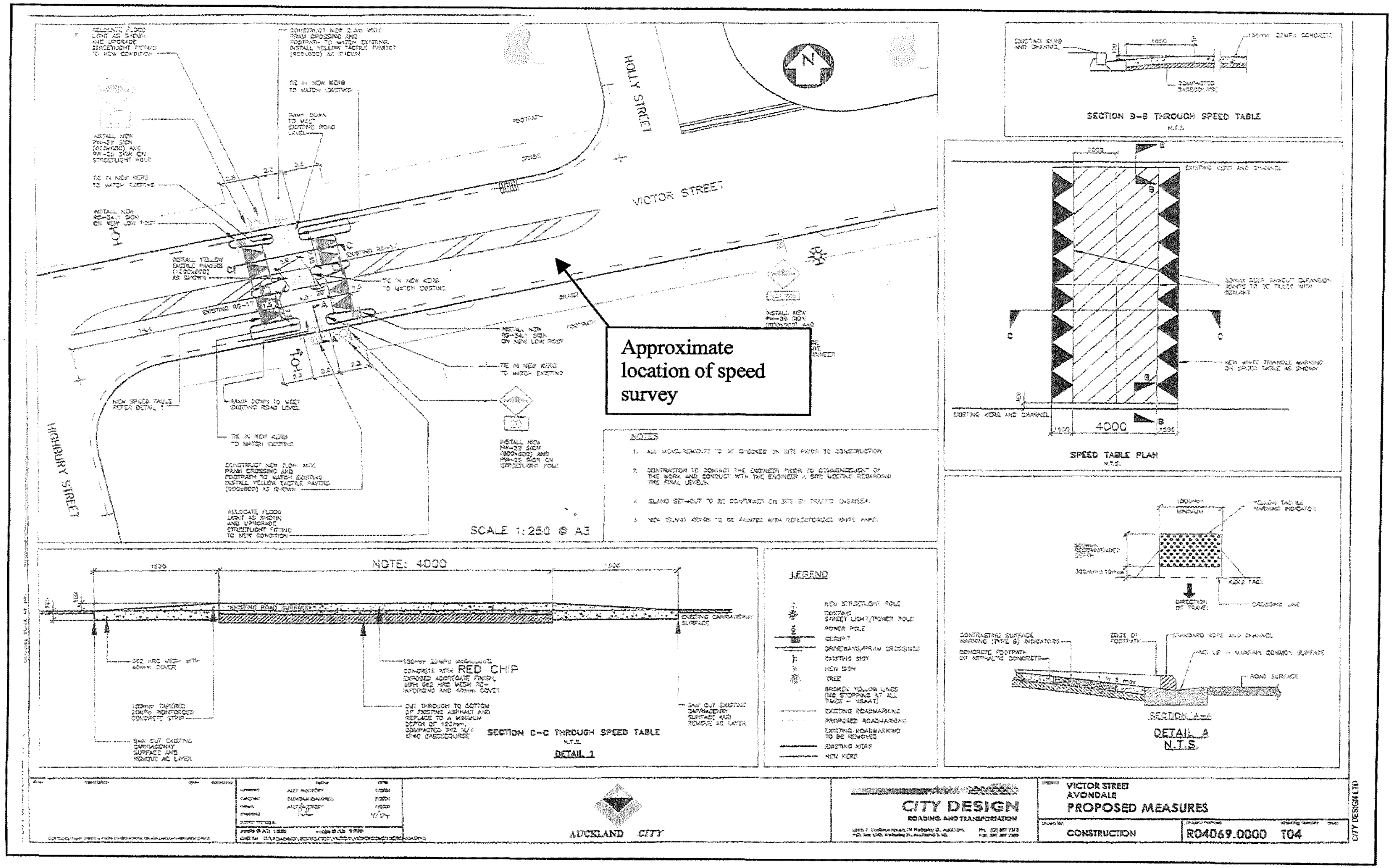
Blackburn LATM, Hamilton

Victor Street – Plan 1 of 3



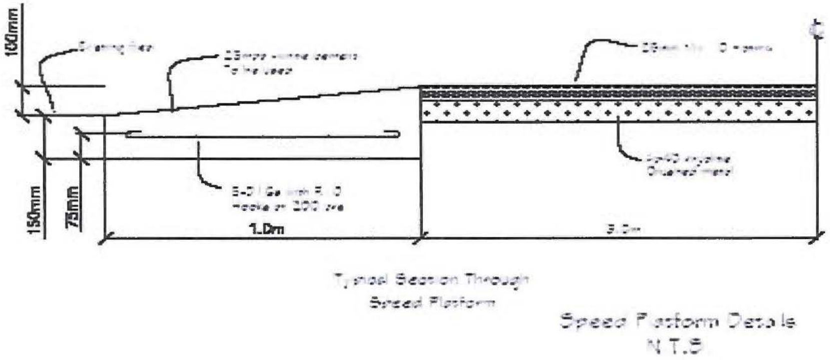

VICTOR STREET
ASPEN STREET
SCALE 1:250@A3
NOTES
SECTION B-B THROUGH SPEED TABLE
SECTION A-A
DETAIL A
N.T.S.
NOTE: 4000
RED CHIP
SECTION C-C THROUGH SPEED TABLE
DETAIL 1
LEGEND
SPEED TABLE PLAN
AUCKLAND CITY
CITY DESIGN
ROADING AND TRANSPORTATION
VICTOR STREET
AVONDALE
PROPOSED MEASURES
CONSTRUCTION
R04069.0000 T03

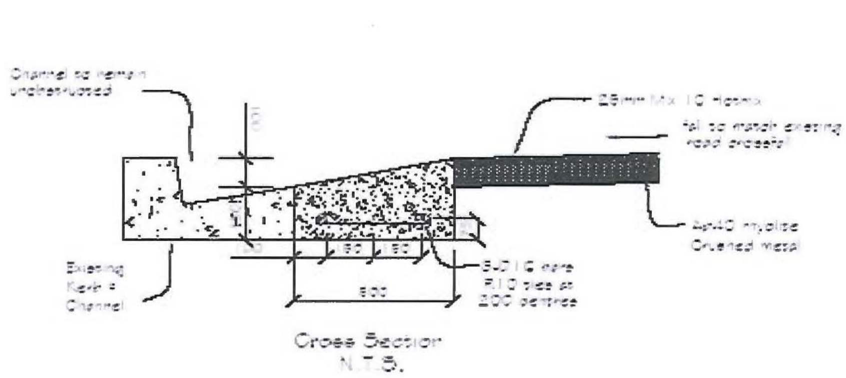
Victor Street - Plan 3 of 3



Konene Street - Plan

Konene Street, Details



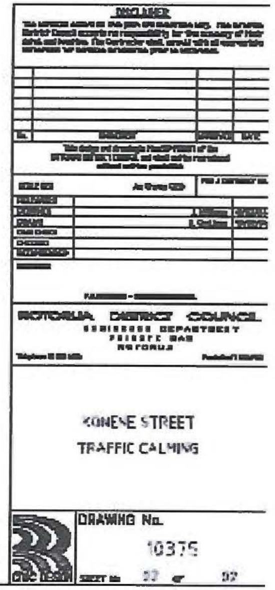


Scale 1:500

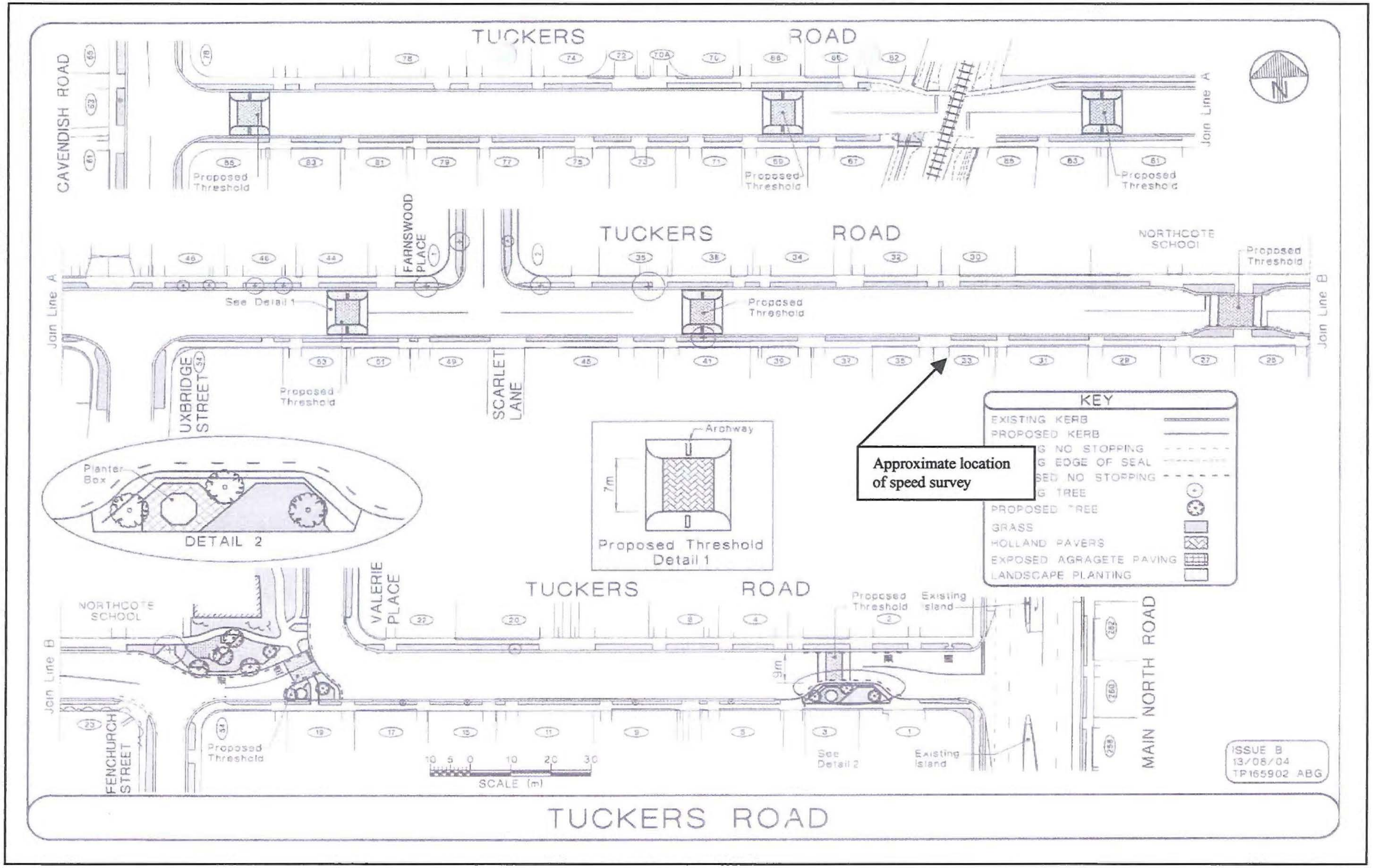
Scale 1:500

Scale 1:500

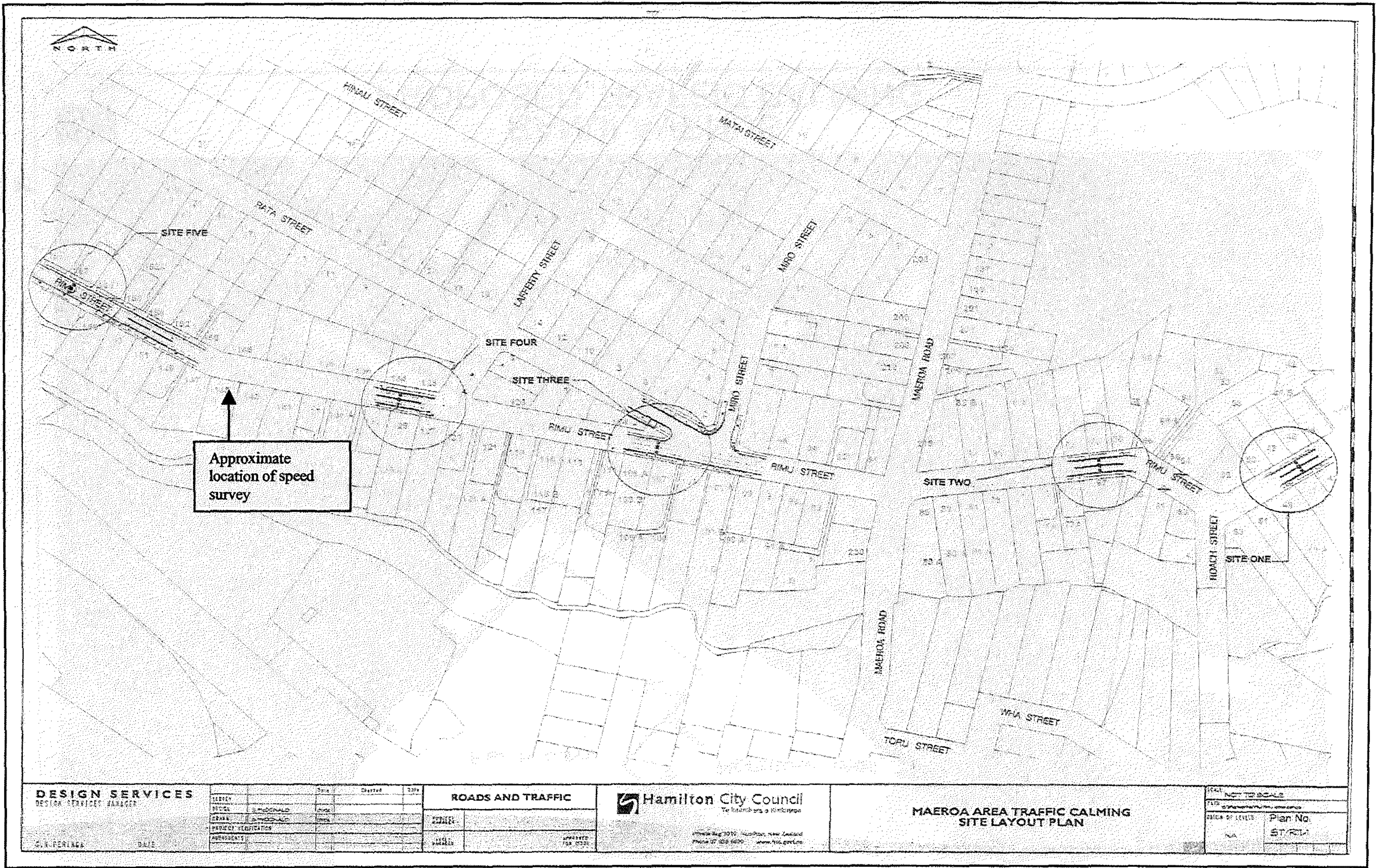
Scale 1:500



Tuckers Road - Plan



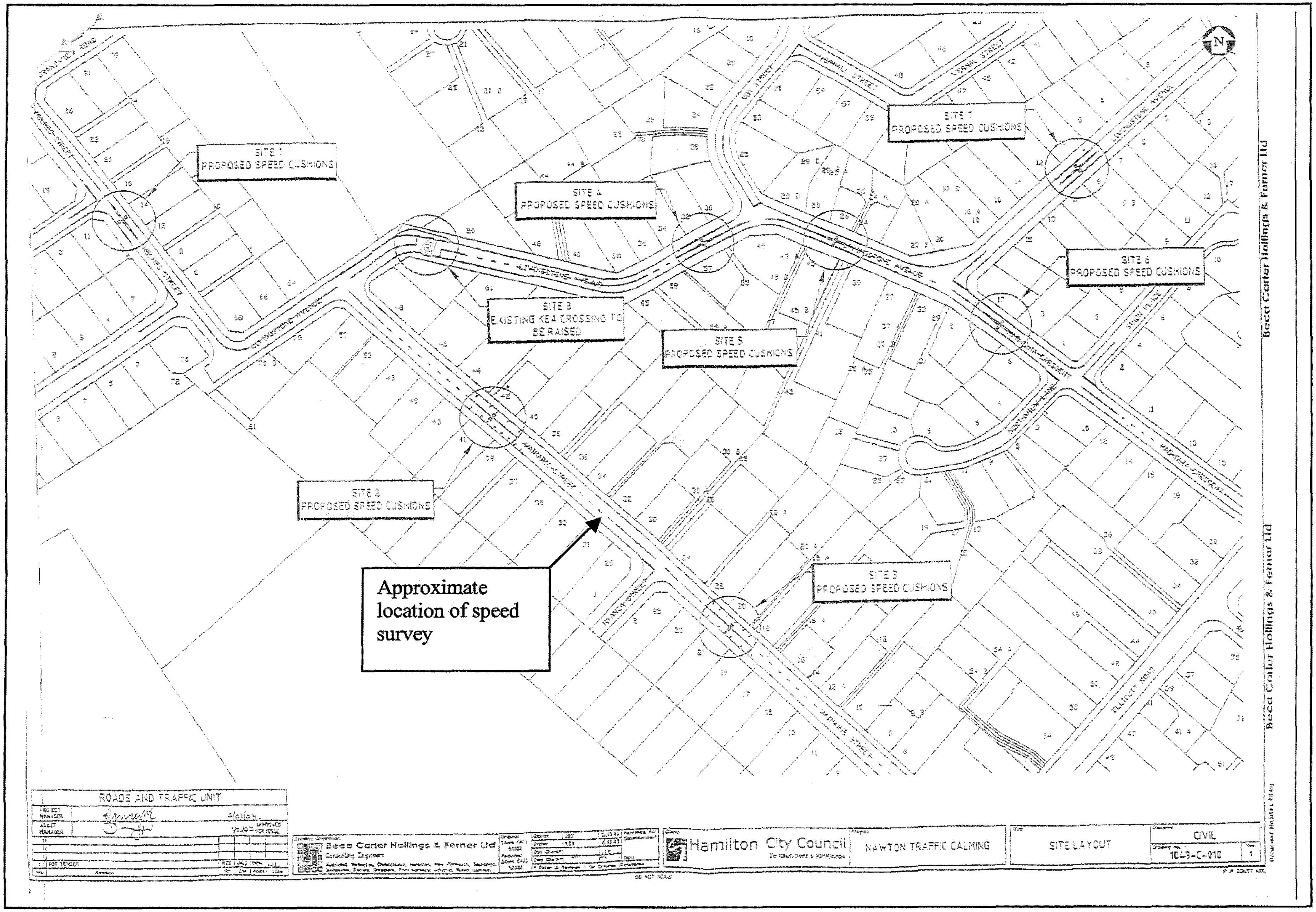
Rimu Street - Plan



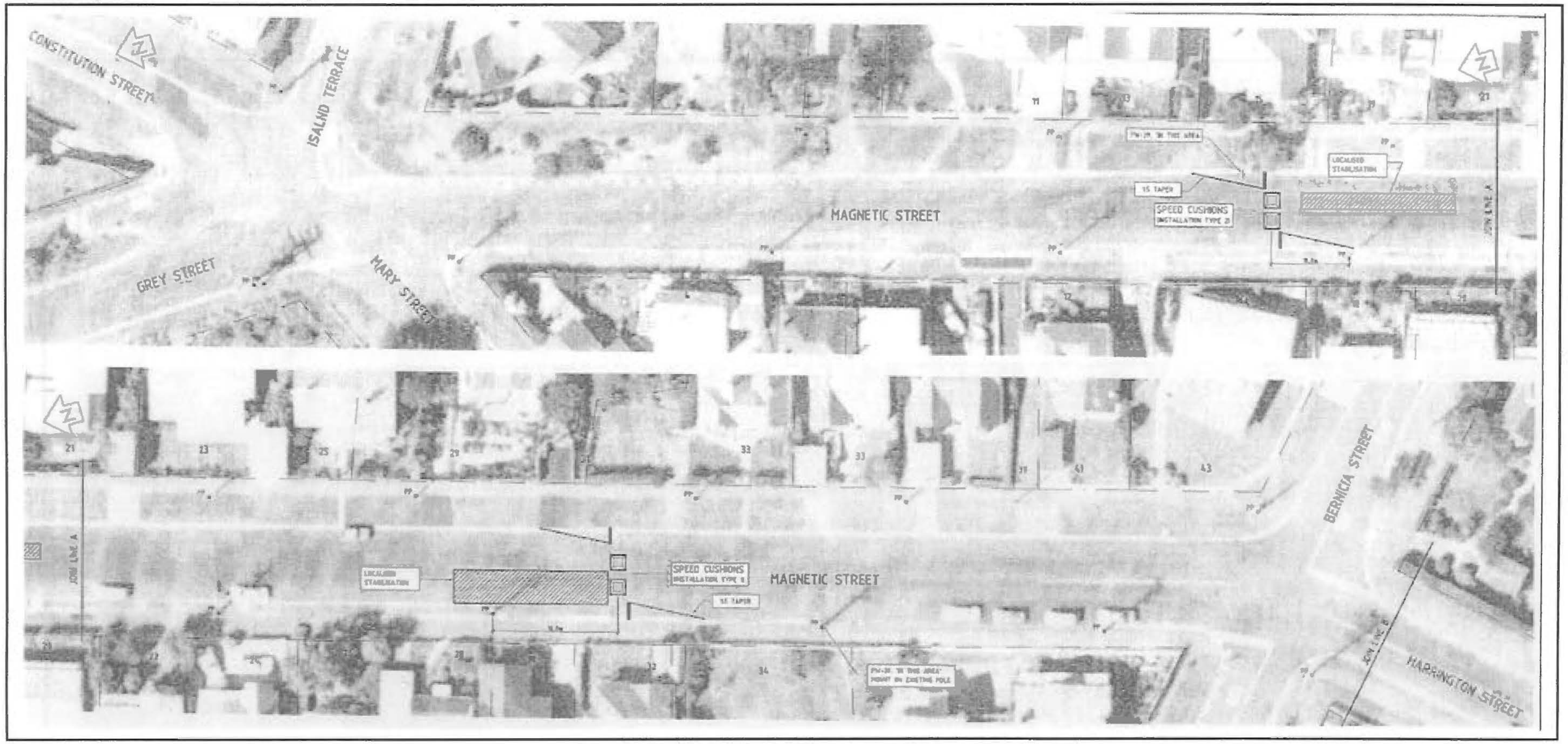
Ranui Avenue – Plan 1 of 2

Ranui Avenue – Plan 2 of 2

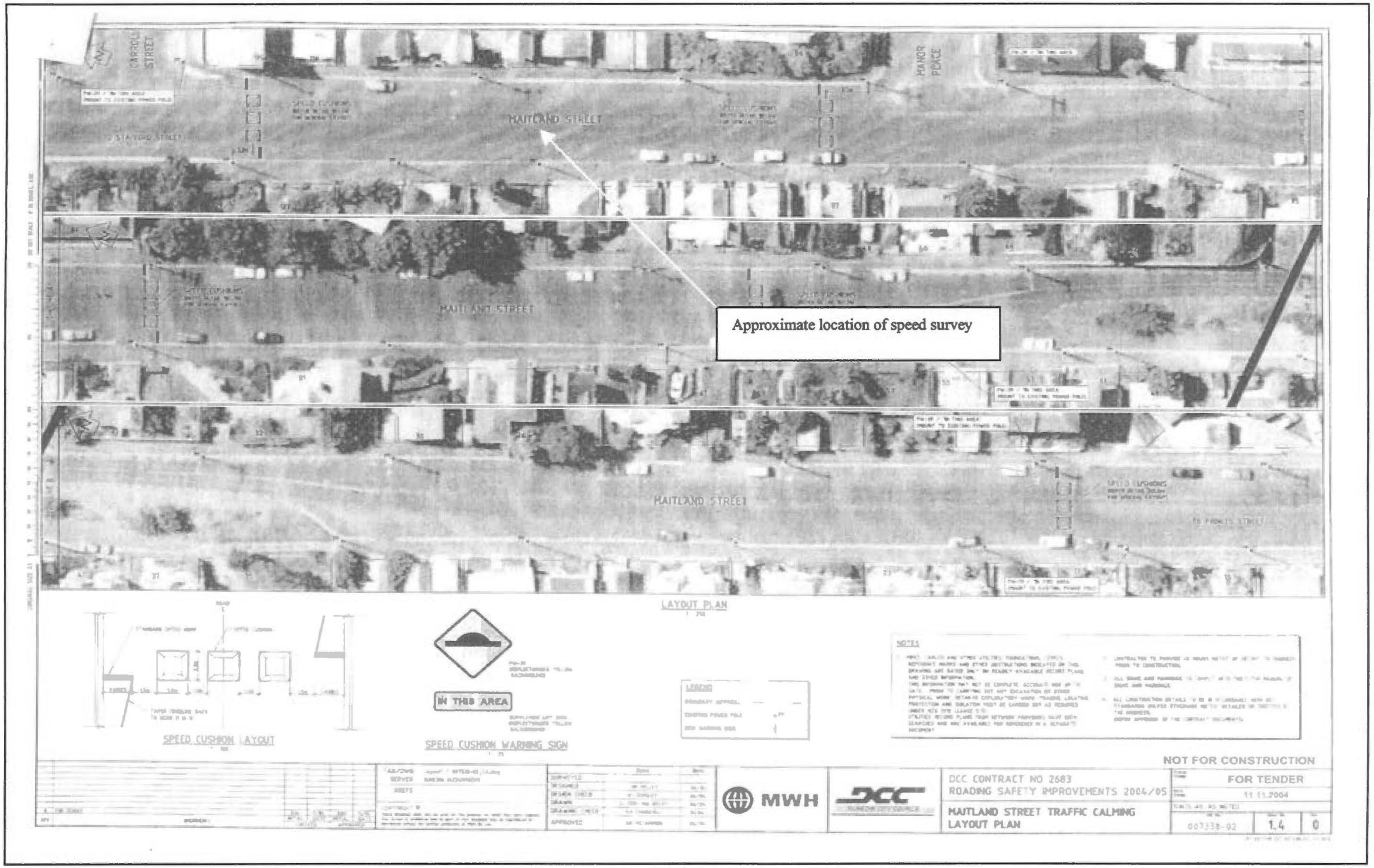
Waimarie Street - Plan



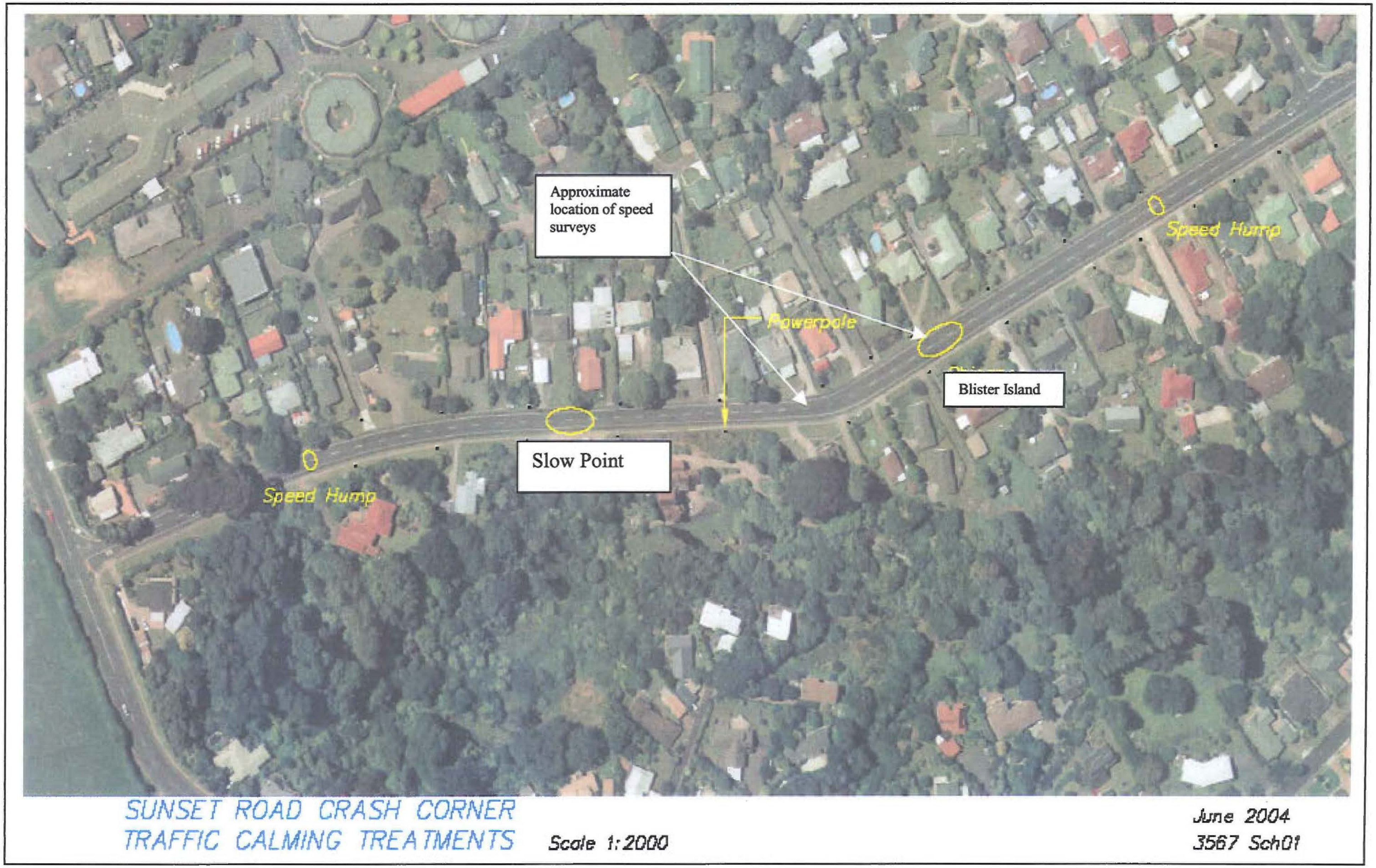
Magnetic Street/Harrington Street - Plan



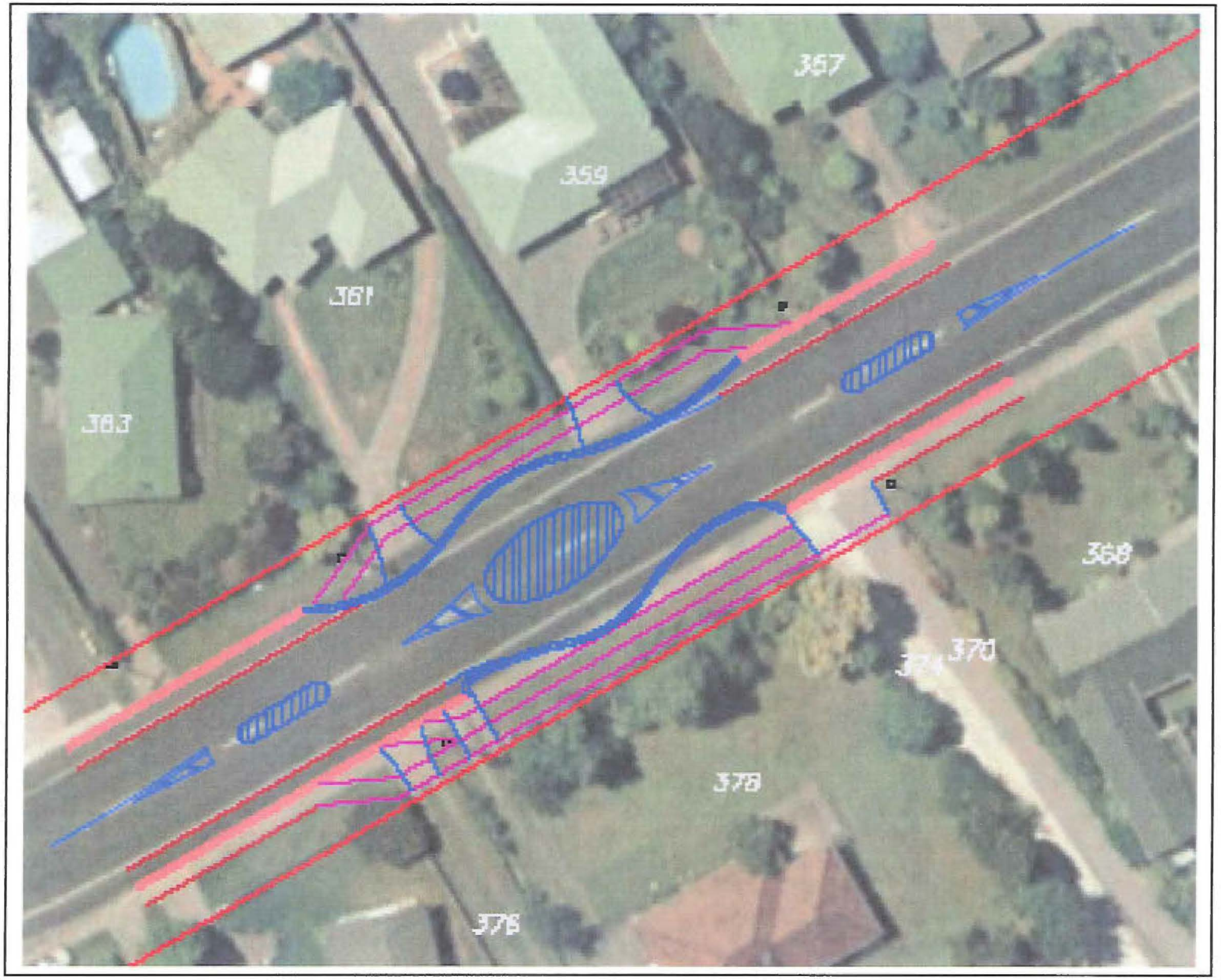
Maitland Street



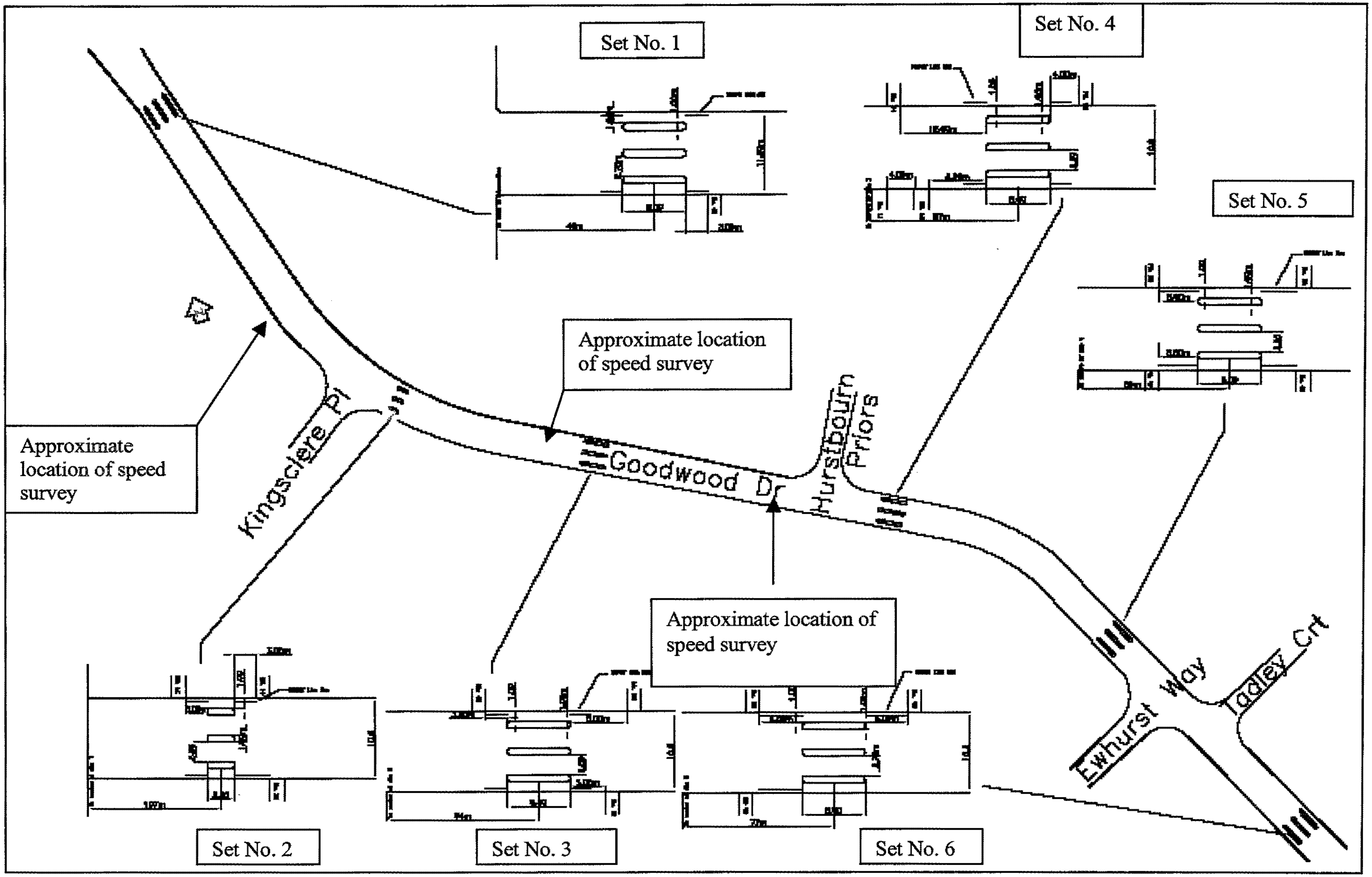
Sunset Road - Plan



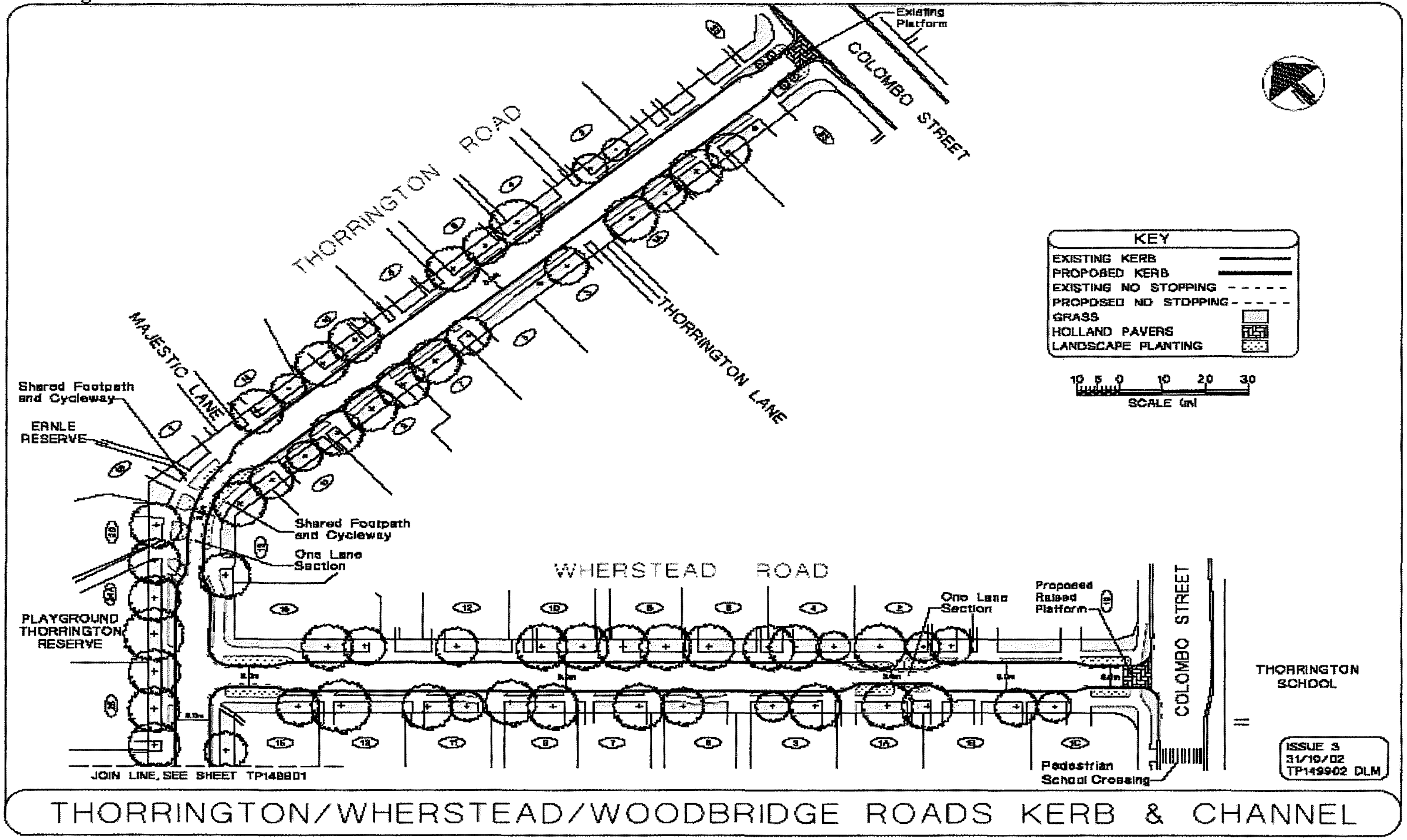
Sunset Road – Plan of Blister Island



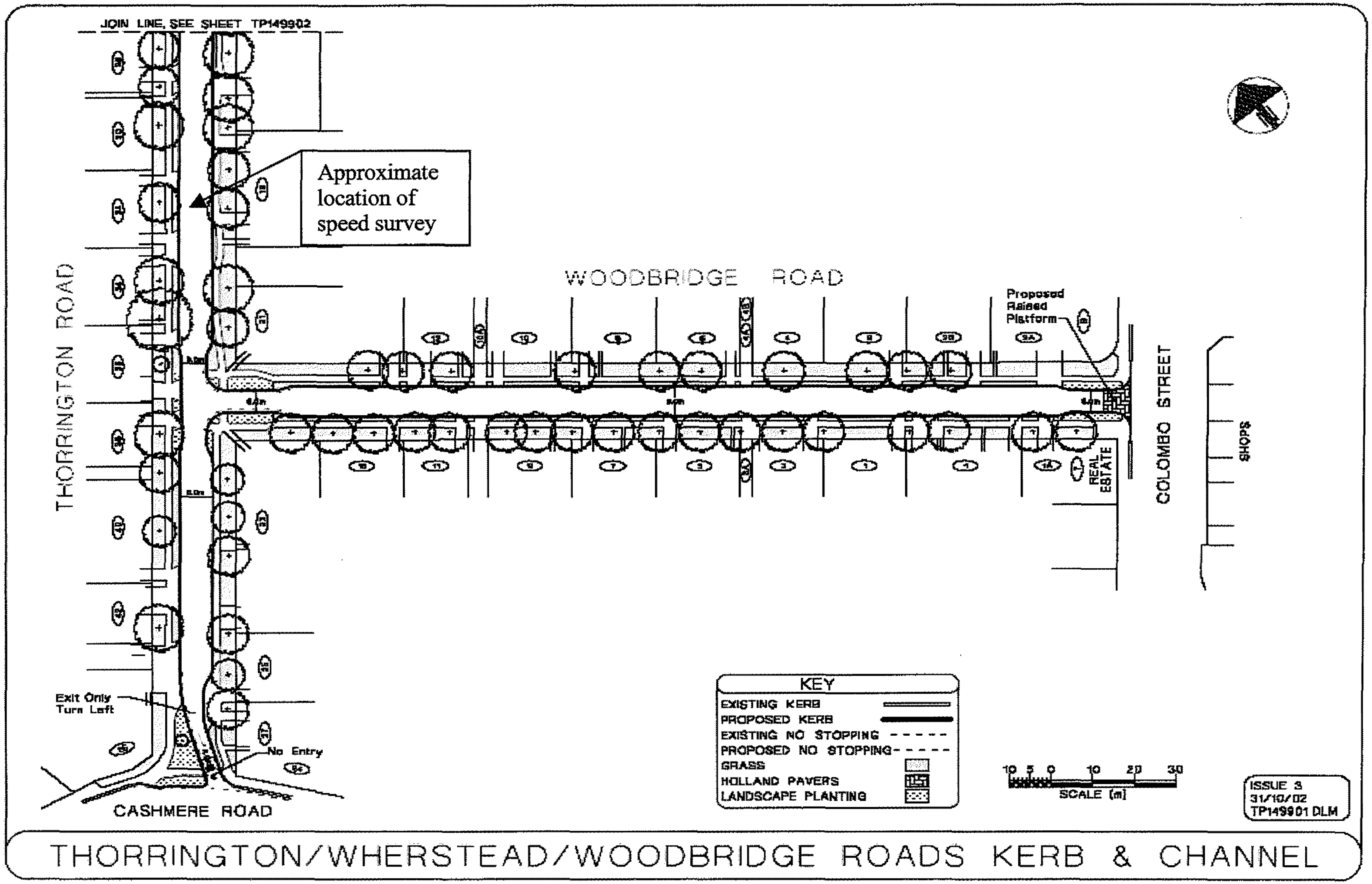
Goodwood Drive - Plan



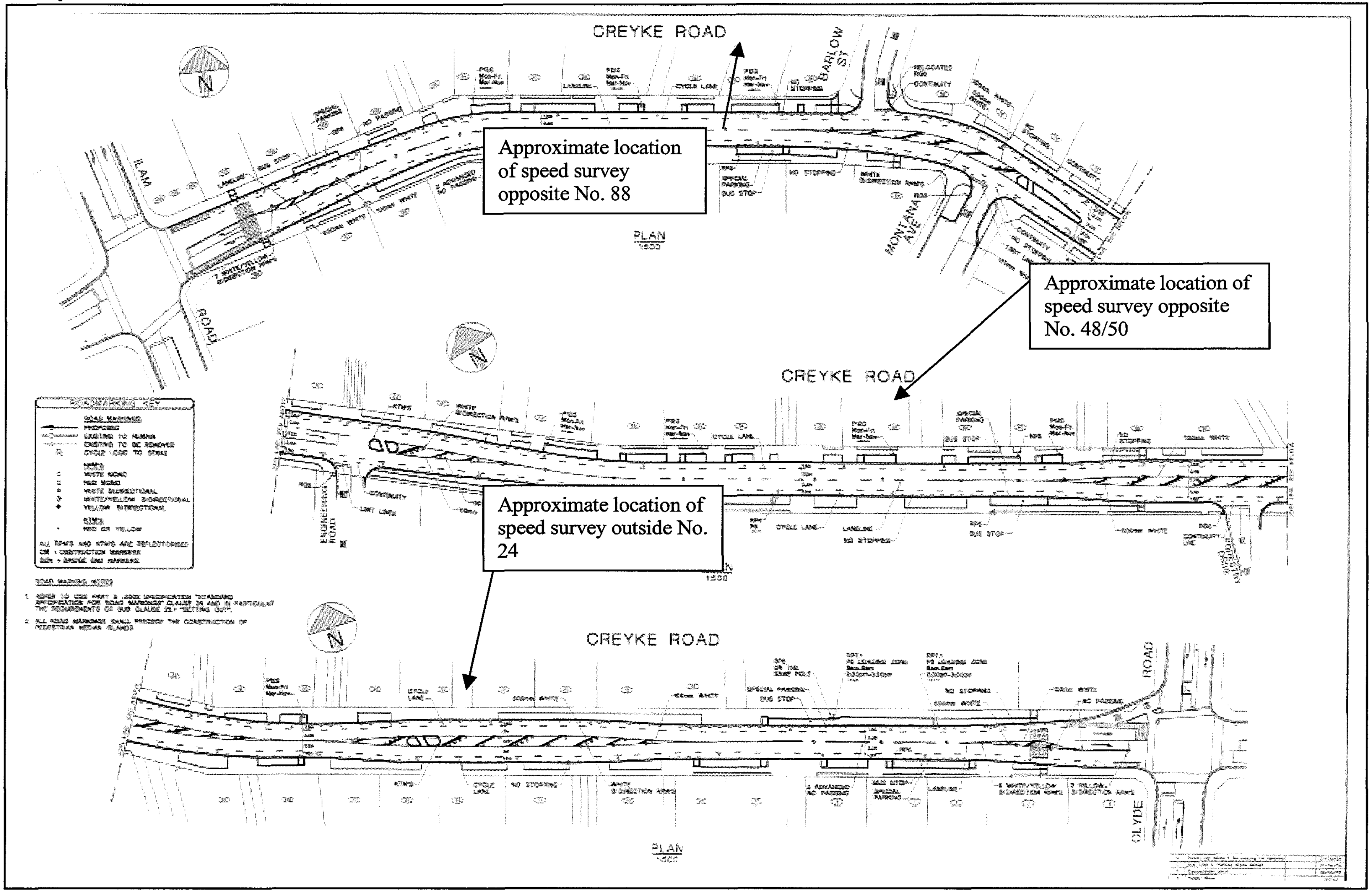
Thorrington Road – Plan 1 of 2



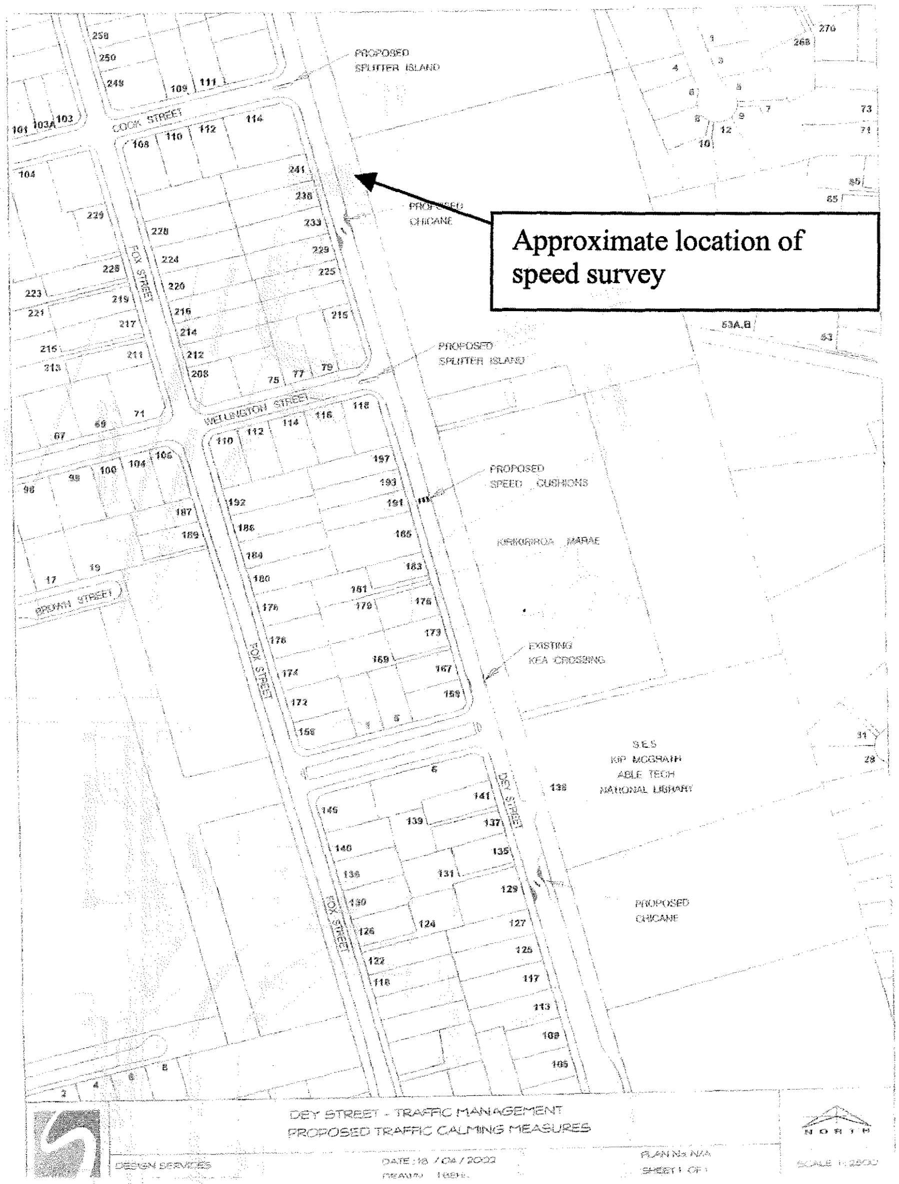
Thorrington Road – Plan 2 of 2



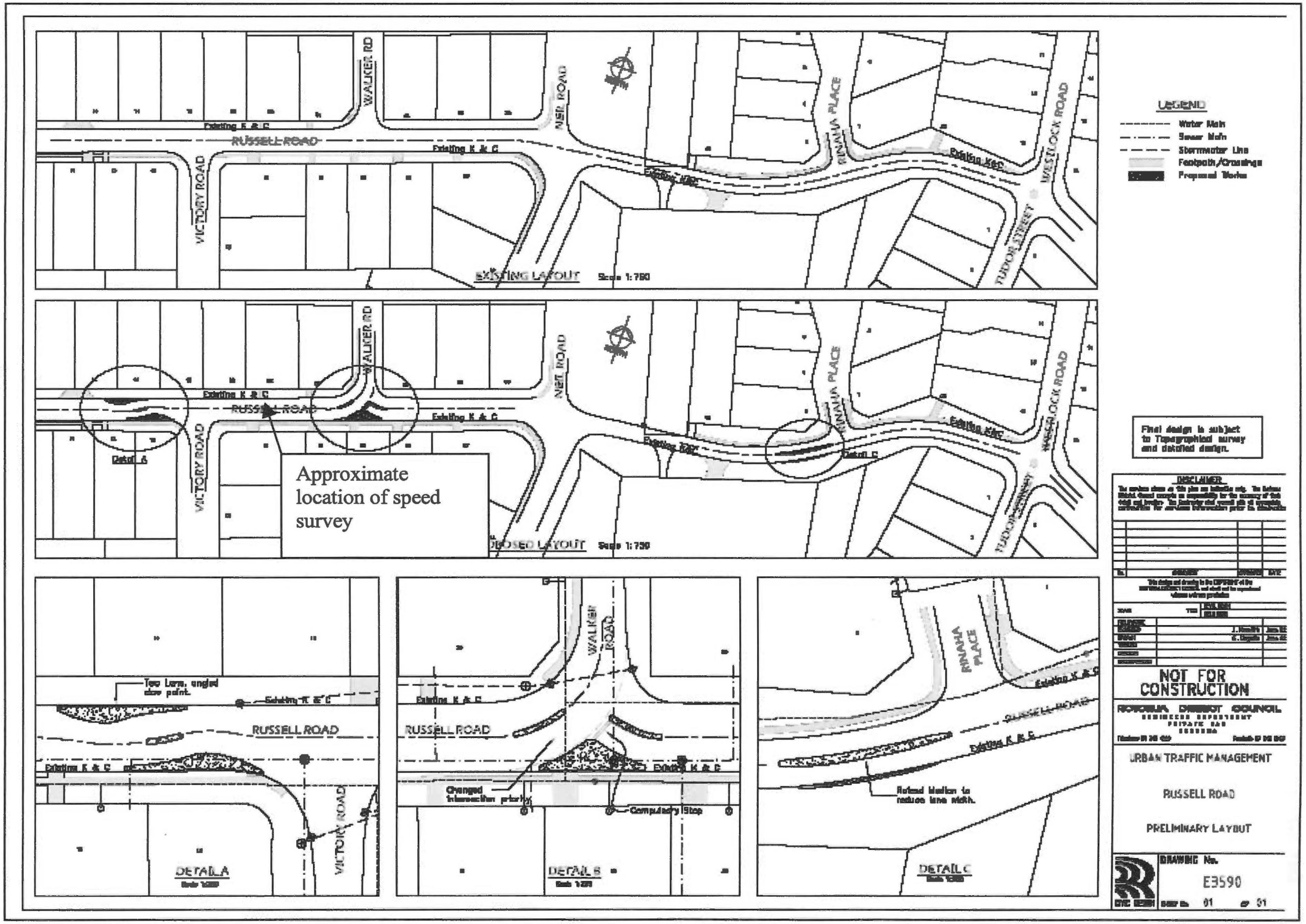
Creyke Road - Plan



Dey Street - Plan



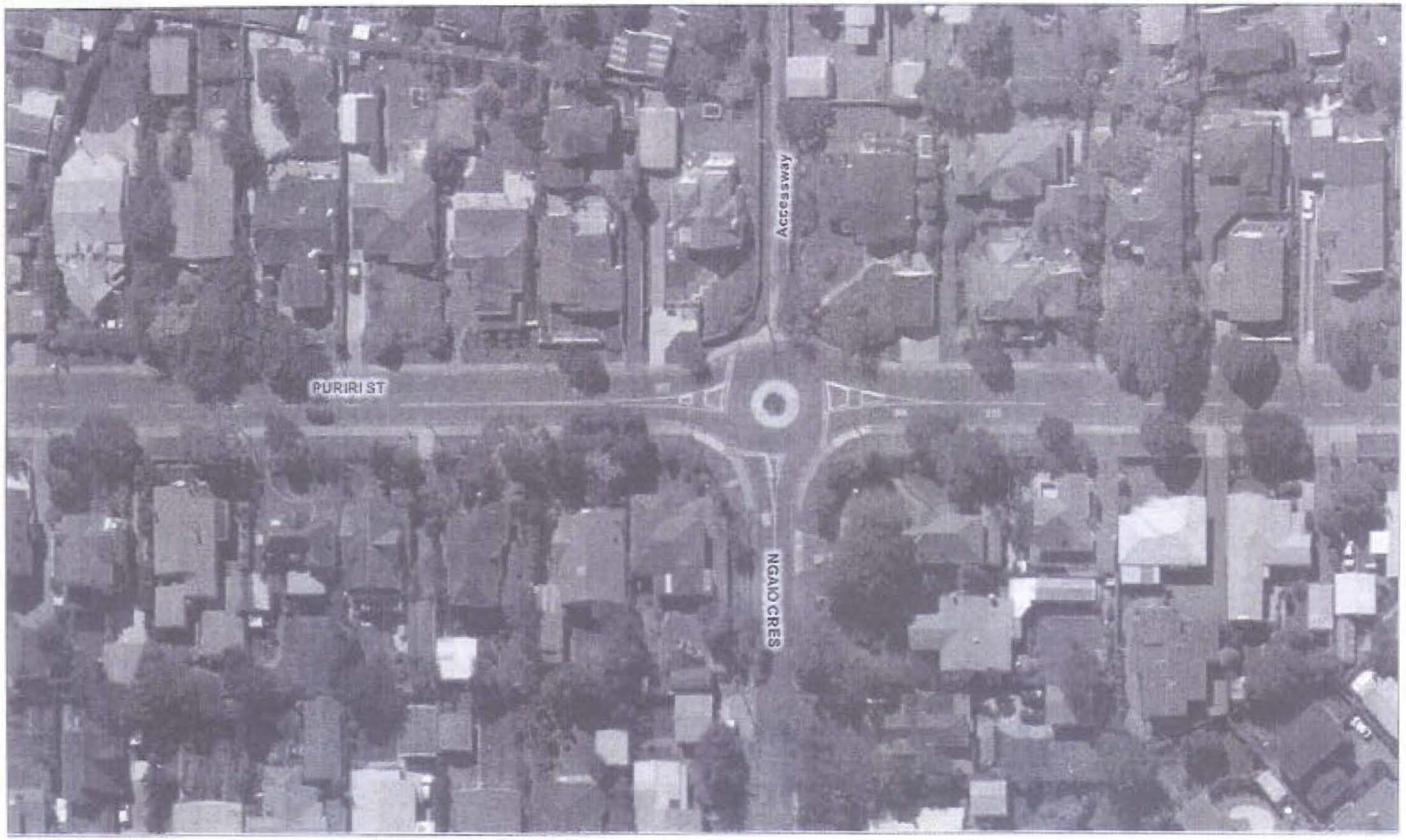
Russell Road - Plan



Puriri Street – Plan 1 of 2

HUTT CITY

Hutt City Council – Property Print Report



Legend

Distances measured from this map are not accurate.

N

Scale 1:1000

IMPORTANT NOTICE :

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Prepared by greigt on 31/05/2005 15:50:54

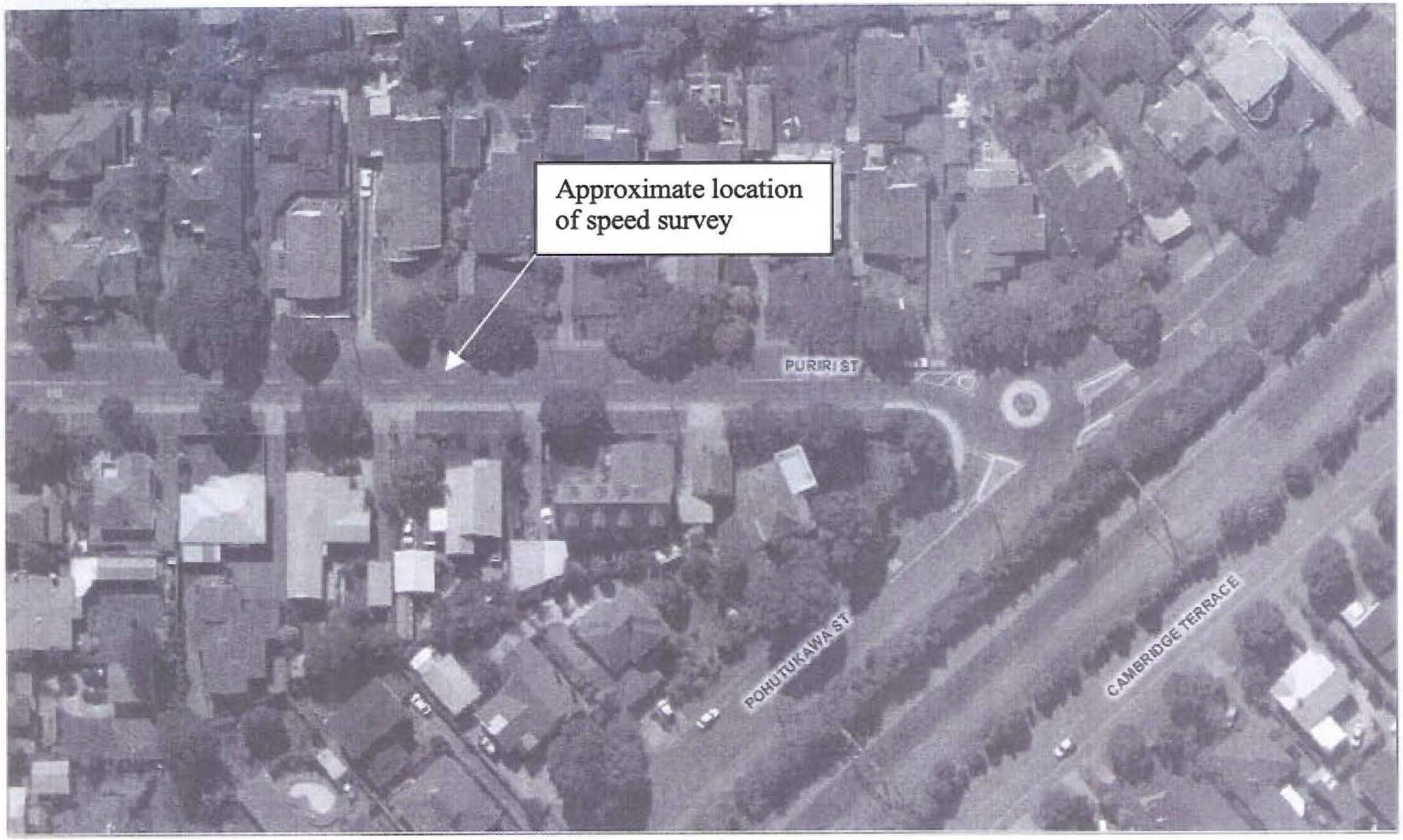
Puriri Street: plan 2 of 2

HUTT CITY

Hutt City Council – Property Print Report

EVIEW

Legend



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Distances measured from this map are not accurate.

Scale 1:1000

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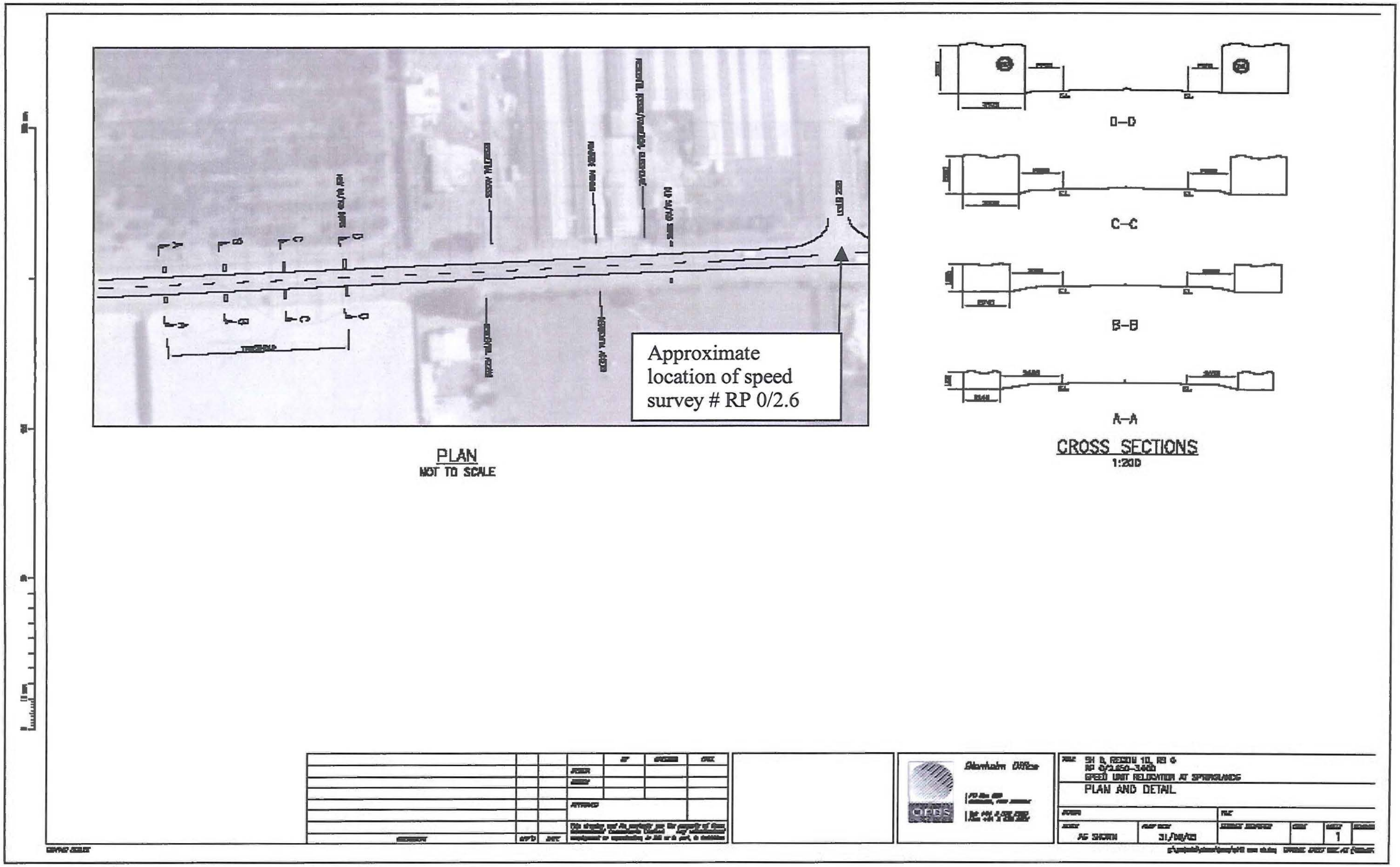
Prepared by greigl on 31/05/2005 15:50:29

Springlands - Plan



Woolwich Street - Plan